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ENCYCLOPEDIA OF ARCHITECTURE.

A

DICTIONARY

OF THE

SCIENCE AND PRACTICE

OF

Architecture, Building, Carpentry, Etc.,

FROM

THE EARLIEST AGES TO THE PRESENT TIME,

FORMING A COMPREHENSIVE WORK OF REFERENCE FOR THE USE OF ARCHITECTS, BUILDERS, CARPENTERS, MASONS, ENGINEERS, STUDENTS, PROFESSIONAL MEN, AND AMATEURS.

BY PETER NICHOLSON,
ARCHITECT AND BUILDER.

EDITED BY
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ARCHITECTS AND CIVIL ENGINEERS.

ILLUSTRATED WITH TWO HUNDRED AND THIRTY ENGRAVINGS ON STEEL,
MOSTLY FROM WORKING DRAWINGS IN DETAIL.

IN TWO VOLUMES
VOL. II

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LIST OF PLATES. VOLUME II.

The Plates of each volume are to be found at the end of the book for greater facility of reference. The page, to which reference is made in the following list, is found at the bottom of each page.

	PAGE
Instruments, Plate I.	12
Do., Plate II.	13
Do., Plate III.	16
Ionic Order, Plate I.	22
Do., Plate II.	22
Do., Plate III.	22
Do., Plate IV.	22
General Plan of St. Paul's, London, and St. Peter's, Rome	45
Bridgewater House elevation	54
Do., plan	54
Joinery, Plate I.	62
Do., Plate II.	65
Do., Plate III.	66
Do., Plate IV.	67
Do., Plate V.	68
Do., Plate VI.	68
Do., Plate VII.	69
Do., Plate VIII.	70
Do., Plate IX.	70
Do., Plate X.	76
Do., Plate XI.	78
Do., Plate XII.	80
Do., Plate XIII.	82
Do., Plate XIV.	84
Do., Plate XV.	85
Do., Plate XVI.	85
Lever, Plate I.	100
St. Geron's Church, Cologne	112
Pisa Cathedral	112
Masonry, Plate I.	120
Do., Plate II.	121
Do., Plate III.	121
Mechanical Carpentry, Plate I.	151
Do., Plate II.	153
Do., Plate III.	156
Do., Plate IV.	159
Do., Plate V.	162
Mouldings, Plate I.	222
Naked Flooring, Plate I.	224
" Plate II.	226
Niches, Plate I.	233
Do., Plate II.	233
Do., Plate III.	233
Do., Plate IV.	234
Five Orders of Architecture	244
Ornaments, Plate I.	245
Oval, Plate I.	246
Do., Plate II.	248
Panorama, Plate I.	257
Do., Plate II.	259
Plan and section of do.	260
Pavement, Plate I.	268
Do., Plate II.	268
Do., Plate III.	268
Pendentive Cradling, Plate I.	273
Pendentive Cradling, Plate II.	273
Perspective, Plate I.	284
Do., Plate II.	285
Perspective of Shadows, Plate I.	286
Pile Driving Machine	292
Planing Machine, Plate I.	304
Do., Plate II.	304
Plumbery, Plate I.	315
Portico, Plate I.	321
Do., Plate II.	321
Projection, Plate I.	330
Do., Plate II.	330
Do., Plate III.	331
Do., Plate IV.	331
Do., Plate V.	332
Do., Plate VI.	332
Do., Plate VII.	332
Do., Plate VIII.	333
Do., Plate IX.	334
Do., Plate X.	335
Do., Plate XI.	335
Do., Plate XII.	336
Do., Plate XIII.	337
Proportional Compasses, Plate I.	342
Raking Mouldings, Plate I.	359
Roman Order, Plate I.	374
Roof, Plate II.	377
Do., Plate III.	378
Do., Plate IV.	379
Do., Plate V.	380
Do., Plate VI.	381
Do., Plate VII.	381
Do., Plate VIII.	390
Sashes, Plate I.	392
Shadows, Plate I.	425
Do., Plate II.	428
Shaft, Plate I.	428
Soffit, Plate II.	434
Do., Plate III.	435
Spandrel Bracketing, Plate I.	437
Stereotomy, Plate I.	446
Do., Plate II.	448
Do., Plate III.	448
Do., Plate IV.	449
Do., Plate V.	449
Do., Plate VI.	449
Stone Bridge, Plate I.	458
Stone Walls, Plate I.	464
Strength of timber, Plate I.	466
Tools, Bricklayers'	494
Do., Carpenters'	494
Do., Joiners'	494
Trigonometry, Plate I.	506
Truss, Plate I.	509
Tuscan Order, Plate I.	514
Do., Plate II.	514
Volute, Plate I.	520
Do., Plate II.	521
Do., Plate III.	521
Do., Plate IV.	521
Windows, Plate I.	526

ARCHITECTURAL DICTIONARY.

ICE-HOUSE, a repository for the preservation of ice during the summer months.

The aspect of an ice-house ought to be towards the south-east, on account of the advantage of the morning sun in expelling the damp air, which is far more prejudicial to it than warmth. The best soil on which such a house can be erected is a chalk-hill, or declivity, as it will conduct the waste water without the aid of any artificial drain; but where such land cannot be procured, a loose stony earth, or gravelly soil on a descent, is preferable to any other.

For the construction of an ice-house, a spot should be selected at a convenient distance from the dwelling-house. A cavity is then to be dug in the form of an inverted cone, the bottom being concave, so as to form a reservoir for the reception of waste water. Should the soil render it necessary to construct a drain, it will be advisable to extend it to a considerable length, or, at least, so far as to open at the side of the hill or declivity, or into a well. An air-trap should likewise be formed in the drain, by sinking the latter so much lower in that opening as it is high, and by fixing a partition from the top, for the depth of an inch or two into the water of the drain, by which means the air will be completely excluded from the well. A sufficient number of brick-piers must now be formed in the sides of the ice-house, for the support of a cart-wheel, which should be laid with its convex side upwards, for the purpose of receiving the ice; and which ought to be covered with hurdles and straw, to afford a drain for the melted ice.

The sides and dome of the cone should be about nine inches thick, the former being constructed of brick-work, without mortar, and with the bricks placed at right angles to the face of the work. The vacant space behind ought to be filled with gravel, or loose stones, in order that the water oozing through the sides may the more easily be conducted into the well. The doors of the ice-house should likewise be made to shut closely; and bundles of straw put before them, more effectually to exclude the air.

The ice to be put in should be collected during the frost, broken into small pieces, and rammed down hard in strata of not more than a foot, in order to make it one complete body; the care in putting it in, and well ramming it, tends much to its preservation. In a season when ice is not to be had in sufficient quantities, snow may be substituted.

ICHNOGRAPHY, (from *ιχνος, footstep*, and *γραφω, to describe*,) an orthographical projection of an object on a horizontal plane, or the description of an object on a plane representing the horizon, by straight lines from all points of the object perpendicular to the plane. This term is used only in reference to a projection of the same nature with another, on which it is made perpendicular to the former, by lines from all points of the object falling perpendicular to such plane, and consequently parallel, to that of the ichnography.

ICOSAHEDRON, (from the Greek, *εικοσαεδρον*,) in geometry, a regular solid, consisting of twenty triangular pyramids, whose vertices meet in the centre of a sphere, supposed to circumscribe it; and therefore have their height and bases equal; wherefore the solidity of one of those pyramids multiplied by twenty, the number of bases, gives the solid content of the icosahedron.

To form or make the icosahedron.—Describe upon a card paper, or some other such like substance, twenty equilateral triangles; cut it out by the extreme edges, and cut all the other lines half through, then fold the sides up by these edges half cut through, and the solid will be formed.

The linear edge or side of the icosahedron being A, then will the surface be

$$5\,A^2\sqrt{3} = 8.6602540A^2,$$

and the solidity $= \frac{5}{6}A^3\sqrt{\frac{7+3\sqrt{5}}{2}} = 2.1816950A^3$.

IMAGE, (from the Latin, *imago*,) the scenographic or perspective representation of an object. *See* PERSPECTIVE.

IMAGERY, painted or carved work.

IMBOW, (from *bow*,) to arch over, to vault.

IMBOWMENT, an arch, or vault.

IMPAGES, (Latin,) in ancient joinery, is supposed to mean the rails of a door, as appears from Vitruvius, book iv. chap 6. "The doors are so framed, that the cardinal scapi may be the twelfth part of the whole height of the aperture. Out of twelve parts between the two scapi, the tympans have three parts. The impages are so distributed, that the height being divided into five parts, two superior and three inferior are disposed. Upon the middle, the middle impages are placed; of the rest some are framed at top, and some at bottom; the breadth of the impage is a third part of the

tympan; the cymatium is a sixth part of the impage; the breadth of the scapi is the half of the impage; the replum is the half and a sixth part of the impage."

IMPETUS (Latin) the span of a building, roof, or arch.

IMPLUVIUM, the cistern in the centre of the atria of Roman houses, to receive the rain, the atria being uncovered.

IMPOST (French) the upper part of a pier or pillar, which sustains an arch; or the collection of mouldings under an arch, forming a cornice of small projection as a finishing to the pier.

INBAND JAMBSTONE, a stone laid in the jamb of an aperture for the purpose of bond: its length being inserted in the thickness of the wall, and showing only its end in the face of it.

INCERTAIN WALL. *See* WALL.

INCH (*ince*, Saxon, *uncia*, Latin) a measure of length, supposed equal to three grains of barley laid end to end; the twelfth part of a foot.

INCLINATION (from the Latin) a word frequently used by mathematicians to signify the mutual approach of a line and a plane, or of two planes, to each other, so as to constitute an angle. In this sense we speak of the inclination of the meridians, the inclination of the sun's rays, &c.

The inclination of a line to a plane, is measured on a second plane, by supposing the second to pass along or through a line perpendicular to the first, and forming an intersection with it: then the angle comprehended on the second plane, between the line and the intersection, is called *the inclination of the line to the plane.*

The inclination of one plane to another, is measured on a third plane drawn perpendicular to the common intersection of the two first, till it intersect them: then the angle contained between the lines of section is *the inclination of the planes.*

INCLINED PLANE, in mechanics, a plane forming an oblique angle with the horizon, or placed at a given angle to another: so that when an inclined plane is spoken of absolutely, another is always to be understood, which is the primitive or first plane, from which the inclined plane rises. When a force, in a given direction, supports a weight upon an inclined plane, such force is to the weight as the sine of the angle made by the line in which the force acts with the line perpendicular to the plane.

Given, the heights of any three points in an inclined plane, and their seats in position upon the primitive plane, to determine the inclination of the planes.—Join the seat of the greatest height to that of the least height, and take the least height from the other two: then say, As the greatest difference is to the least difference, so is the whole length of the line joining the two seats to the portion of it between the seat of the least height and that of the greatest; join the intermediate point to the seat of the mean height by a straight line, which call AB; draw a straight line, CD, perpendicular to AB; through the seats of the greatest and least heights draw two lines, CE and DF, parallel to AB; make CE equal to the greatest height, and DF equal to the least; join EF, and produce CD and EF to meet in G; then the angle CGE is the inclination of the planes.

INCRUSTATION (French) an adherent covering. This term is frequently applied to plaster, or other tenacious materials employed in building.

INDEFINITE (from the Latin *indefinitus*, not limited) is sometimes used to express something that has but one extreme; as a line drawn from any given point, while the other extremity is extended infinitely, or to any given distance, without affecting its use.

INDENTED (from the Latin *in*, and *dens*, a tooth) in architecture, toothed together.

INDIAN ARCHITECTURE, the style which was practised by the inhabitants of India. Although what relates to India was anciently but very imperfectly known to the western world, yet such is the change in human affairs, and the eagerness with which every matter relating to India has of late been investigated, that we are now furnished with accounts fully as ample as those relating to Egypt or Persia. In the following brief relations we shall be guided by some excellent papers, by Sir William Jones and others, in the *Asiatic Researches;* Robertson's *Disquisitions respecting Ancient India;* the learned and laborious work of Maurice on *Indian Antiquities;* and several other authorities quoted for particular descriptions.

In India, the cities and palaces were on a scale with its great wealth and population. They were generally indebted for their origin to the favour of powerful princes, and successively became the centre of the riches and traffic of the East. In the historical poem, called the *Mahabbarit* (or History of the Great War) translated by Abul Fazel, the secretary or minister of the great Akbar, it is said, that Oude, the capital of a province of that name, to the north-east of Bengal, was the first regular imperial city of Hindoostan, and that it was built in the reign of Krishen, one of the most ancient rajahs. The *Ayeen Akbery* (vol. ii. p. 41) represents Oude to have anciently been 148 coss (or about 259 miles) in length, and 36 coss (or about 53 miles) in breadth; but this bears more resemblance to a province than a city. "This city," says Sir W. Jones, "extended, if we may believe the brahmins, over a line of ten yojans (or 40 miles.) It is supposed to have been the birth-place of Rama." According to the *Mahabbarit*, Oude continued the imperial city 1,500 years, until about the year 1,000 before the Christian era, when a prince of the dynasty of the Surajas, who boasted their descent from the sun, erected Canouge upon the banks of the Ganges, and made the circumference of its walls 50 coss, or about 87 miles. Strabo, from Megasthenes, who had seen Canouge, says it was situated at the confluence of another stream with the Ganges; that its form was quadrangular, the length 80 stadia, breadth 15, or, taking the mean stadium of the ancients, about 8 miles by $1\frac{1}{2}$; that it had wooden fortifications, with turrets for archers to shoot from, and was surrounded by a vast ditch.—Strabo, lib. xv. p. 667. Arrian calls it the greatest city amongst the Indians; he says that it was situated at the junction of the Erannaboa with the Ganges: he gives the same dimensions as Strabo; and says, that there were 570 towers on the walls, and 65 gates. Diodorus Siculus, lib. xvii. says, that when Alexander passed the Hyphasis, he was informed, that on the banks of the Ganges, he would meet the most formidable sovereign of India, called Xambranes, king of the Gangarides, at the head of 20,000 horse, 200,000 foot, 2,000 war-chariots, and 4,000 fighting elephants. The *Mahabbarit* states that Sinkol, a native of Canouge, brought into the field, against Affrasiah, king of Persia, 4,000 elephants, 100,000 horse, and 400,000 foot. But that after Delu had founded Delhi, and established his court there, Canouge declined, and was involved in civil discord;—still we learn from the same authority, that Sinsarchand, or Sandrocottus, the successor of Porus, restored Canouge to its ancient splendour; and that here, about the year 300 before Christ, he entertained the ambassadors from Seleucus, the successor of Alexander, and that Megasthenes was amongst the number. In the beginning of the fifth century, Ramdeo Rhator (or the Mahratta) entered Canouge in triumph, and reigned there 54 years. The last king under whom this city may be considered as the metropolis of a great

empire, was Maldeo, who, about the beginning of the sixth century, added Delhi to his dominions. At this time, Canouge was said to contain 30,000 shops in which areca was sold. Although not the metropolis, it long after continued of great consequence. About the year 1,000, when Sultan Mahmed invested it, it is represented as a city which, in strength, has no equal. It became an appendage to the empire established by Mahmed.—*Ferishta*, vol. i. p. 27.

Major Rennell is of opinion that Canouge and Palibrothra were the same. Others endeavour to prove the contrary; and that both may have existed at the same time capitals of the Prasii, as Delhi and Agra have done in later times.

The precise period of the origin of Delhi is not correctly ascertained: according to the *Ferishta*, it was founded by Delu, who usurped the throne about 300 years before Christ. The *Ayeen Akbery* fixes it about the commencement of this æra, and informs us, that twenty princes of the name of Bal, or Paul, followed in regular succession for 437 years; that the last of its native princes was Pithoura, when it was conquered by the Mahomedan slave Cattub, named by Herbelot, Cathbaddin Ibek, who made Delhi the capital of the vast empire he established in Hindoostan; and that each successive monarch of the Mahomedan dynasty adorned it with splendid edifices, appropriated to the purposes of religion and commerce. At the invasion of Timur Beck, it had arrived at the highest distinction for commerce and wealth, being then the centre of the traffic carried on between Persia, Arabia, and China. Timur entered it on the 4th July, 1399; and on the 13th of the same month, this celebrated city was destroyed. Sherifedden, the Persian historian, says, that old Delhi was celebrated for a mosque and palace, built by an ancient Indian king, in which were a thousand marble columns. Under the dynasty which succeeded Timur, it recovered its original splendour, and was again ornamented with mosques, baths, caravanseras, and sepulchres.

The great Akbar, the glory of the Timur house, having fixed his residence at Agra, Delhi, of course, experienced a partial eclipse; but in 1647, according to Fraser, Ischaim Shah, the grandson of Akbar, restored Delhi under the name of Ischaimbad, where he built a magnificent palace, formed extensive gardens, and constructed a throne in the shape of a peacock, whose expanded tail was entirely composed of diamonds, and other precious stones. It continued the capital of Hindoostan till 1738, when it was sacked by Nadir; and afterwards repeatedly by Ahmed Abdallah, from 1756 to 1760, when it was totally destroyed. During the reign of Aurungzebe, it was said to contain two millions of inhabitants.

Lahore is situated to the north-west of Delhi, on the banks of the Rauvee, the ancient Hydraotes: it appears to have been the Bucephalus of Alexander. Jeipal, the rajah of Lahore, during the incursions of Subuitagi, and his son Mahmud, defended his possessions with great bravery, and so great were his riches, that, when taken prisoner, around his neck alone were suspended sixteen strings of jewels, each of which was valued at 180,000 rupees, and the whole at £320,000. Lahore continued to flourish under the sultan of Cosro, and was the imperial seat of Cuttub before he removed it to Delhi; even afterwards it remained the general storehouse for the traffic of Persia, Arabia, India, and China. It was restored by Homaion, who amongst other magnificent buildings, erected a palace, which was completed by Ischaim Geer, the son of Akbar. This palace, according to Mr. Finch, who visited it in 1609, had twelve gates, nine towards the land side and three towards the river. He says, the rarities were too numerous and glorious to be represented in a description; that the mahls, courts, galleries, and rooms of state, were almost endless; and that, in the king's lodgings, the walls and ceilings were overlaid with plates of gold. M. Bernier, who was in this city in the suite of Aurungzebe, speaks of this place as a high and magnificent building, but then hastening to ruin.

Agra, the Agara of Ptolemy, situated in 27° 15′ north latitude on the banks of the Jumna, we have already observed, was raised to splendour by the great Akbar. He caused the earthen wall, by which the city had been enclosed by the Patan monarchs, to be taken away and replaced by one of hewn stone, brought from the quarries of Fettipore. He collected the most skilful artificers from every part of his dominions; and the palace alone employed above 1,000 workmen for twelve years. The castle was built in the form of a crescent, upon the banks of the Jumna; and in a line with it were ranged the palaces of the princes and great rajahs, intersected with canals and beautiful gardens. Akbar also erected many caravanseras and mosques. He invited foreigners of all nations; he built them factories; and permitted to all the free use of their religion. It was soon crowded with Persian, Arabian, and Chinese merchants, besides those immediately from European settlements. But when Ischaim removed the imperial insignia and treasures to Delhi, and made it the residence of his court, Agra sunk rapidly to decay.

These five imperial cities seem, with regard to extent, splendour, and wealth, to have exceeded the greatest cities of the western world; and, besides these, many others were almost of equal magnificence: for Chundery is said to have contained 384 markets, and 360 caravanseras; and Ahmedabad was once so large as to require to be divided into 360 quarters.—Maurice, *Ind. Antiq.* vol. i. p. 118–124.

These extensive and proud cities were evidently the symbols of temporary policy and power, and have passed away, like so many splendid scenes on the great theatre of the East. But as the religion of India has been more permanent than their political relations, it is from the sacred edifices we are to trace most distinctly the characters of Indian architecture, and be enabled to judge how far they have any affinity with those of other nations. Of their large temples, (pagodas) we find accounts of five different forms.

1. Simple pyramids constructed of large stones, and diminished by regular recesses or steps, as at Deogur and Tanjore; the exterior rude, and the interior having only light from without by a small entrance door; illuminated by a profusion of lamps, with the exception of a chamber in the middle, which has only a single lamp. Aquetil says, that to him one of the mountains of Canara seemed hewn to a point by human art.

2. The second kind were formed by excavations in the sides of rocky mountains. Abul Fazul (*Ayeen Akbery*, vol. ii. p. 208) says, that in the soobah of Cashmere, in the middle of the mountains, 12,000 recesses were cut out of the solid rock. From Captain Wilford's paper on Caucasus, inserted in the sixth volume of the *Asiatic Researches*, we learn that an extensive branch of the Caucasus was called by the Greeks Parapamis, obviously derived from Para Vami, the pure and excellent city of Vami, commonly called Bamiyan. It is situated on the road between Balkh and Cabul, and like Thebes in Egypt, consists of vast numbers of apartments and recesses cut out of the rock; some of which, on account of their extraordinary dimensions, are supposed to be temples. There are also, at that place, two colossal statues, one of a man eighty ells high, and another of a woman fifty ells high, erect and adhering to the mountain from which they are cut. At Salsette, Elephanta, and Vellore or Ellora, the excavations were not only extensive, but were divided into separate apartments, with regular ranges of sculptured pillars and

entablatures, and the walls and ceilings covered with multitudes of figures of their genii, deutah, men, and women; and various animals, such as elephants, horses, lions, &c. all of the most excellent workmanship. See *Plates* I. and II.

3. A third set was composed of square or oblong courts of vast extent. The circumference of the outward wall of that in the island of Seringham, adjacent to Trichinopoly, is said to extend nearly four miles. The whole edifice consists of seven square enclosures, the walls being 350 feet distant from each other. In the innermost spacious square are the chapels. In the middle of each side of each enclosure-wall there is a gateway under a lofty tower: that in the outward wall, which faces the south, is ornamented with pillars of single stones, thirty-three feet long, and five in diameter.—*Voyages de M. Sonnerat*, tom. i. p. 217; and Robertson's *India*, p. 268. Tavernier describes the pagoda of Santidos, in the Guzerat, as consisting of three courts paved with marble, and surrounded with a portico supported by marble columns; the inside of the roof and walls formed of mosaic work and agates, and all the portico covered with female figures cast in marble. Aurungzebe profaned this temple by killing a cow within its precincts, and converting it into a Turkish mosque. At Chittambrum, on the coast of Coromandel, there is only one court, 1,332 feet in one direction, and 936 in another, with an entrance gateway under a pyramid 120 feet high, and the ornamental parts finished with great delicacy.—John Call, *Phil. Trans.* vol. lxii. p. 354. Orme's *Hist.* vol. i. p. 178.

4. A fourth sort, as Benares pagoda, in the city of Casi, which from the earliest times was devoted to Indian religion and science. The temple is in the form of a cross, with a cupola terminated by a pyramid in the centre, and having also a tower at each extremity of the cross. From the gate of the pagoda to the Ganges, there is a flight of steps.—*Tavernier*, tom. iv. p. 149. Rouen edit.

5. A fifth are made in a circular form, as the celebrated pagoda of Juggernaut, which Hamilton compares to an immense butt set on end. Juggernaut is only another name of the god Mahadeo, who is represented by the vast bull which juts out of the eastern aspect of the building. It is the seat of the arch-brahmin of all India, and its sacred domains are said to afford pasturage for 20,000 cows.

Besides these general terms, if our limits permitted us to trace those interesting structures through the various districts of this extensive country, many different arrangements might be described; but, for the present, we must be satisfied with mentioning the pagoda of Bezoara, (or Buswara of Major Rennell,) now a fort upon the Kistna river: it was not enclosed with walls, but erected upon 52 lofty columns with statues of Indian deities standing between the columns. It was situated in the midst of an oblong court, around which there was a gallery raised on sixty-six pillars, like a cloister. —*Voy. des. Ind.* tom. iii. p. 226. Rouen Ed. 1713. Near this, on a hill ascended by one hundred and ninety-three steps, was another pagoda of a quadrangular form, terminated by a cupola.

These temples were generally erected on the banks of the Ganges, Kistna, and other sacred rivers, for ablution. Where there was no river, a tank or reservoir of a quadrangular form was constructed, and lined with free-stone or marble, with steps descending into them. Crawford observed many 300 or 400 feet in breadth.—Crawford's *Sketches*, vol. i. p. 106. At the entrance of the principal pagodas, there is a portico supported by rows of lofty columns, and ascended, as in the case of Tripetty, by more than one hundred steps; under these porticos, and in the courts which generally enclose the buildings, multitudes attend at the rising of the sun, and having bathed, and left their sandals at the border of the tank, impatiently await the unfolding of the gates by the ministering brahmin.—*Thevenot.*

We must reserve, until we come to treat of the detail of Indian architecture, many particulars relative to those splendid edifices, which, with the plates accompanying them, will afford a more distinct view of the nature of their arrangements and appropriations; but it will be proper in this place to notice some leading circumstances respecting the Indian sculptures, with a view to ascertain what affinity they had to those in Egypt. From the *Ayeen Akbery*, and Captain Wilson's paper on Caucasus, we find, that in the Soubah of Cashmere, between Balkh and Cabul, in the numerous excavations, there were 700 places where the figure of a serpent was carved; and that near these excavations, there were sculptured in rock, on the side of the mountain, figures of 15, 50, and 80 ells high; that in the great temple of the sun, which was near Juggernaut, and said, by the *Ayeen Akbery*, to have consumed, in the expense of building, the whole revenue of the Orissa for twelve years; that in front of the gate, there was a pillar of black stone, of an octagon form, 50 cubits high; that at the eastern gate, there were two elephants, each with a man on his trunk; at the western gate were figures of horsemen, completely armed; and at the northern gate two tigers, who had killed two elephants, and were sitting upon them. That in one extensive apartment, there was a large dome constructed of stone, upon which was carved the sun and stars, and around them a border of human figures. In the pagoda at Juggernaut, Hamilton describes the idol as a huge black stone, of a pyramidal form; and there was a bull, representing the god Mahadeo, jutting from the wall of the eastern aspect. Tavernier observed a conspicuous idol of black stone in the temple of Benares; and that the statue of Creeshna, in his celebrated temple of Mathura, was of black marble. In the great pagoda at Elephanta, the bust of the triple-headed deity measures 15 feet from the base to the top of the cap, the face is five feet long, and it is 20 feet across the shoulders. Along the sides of the cavern are colossal statues, to the number of forty or fifty, from 12 to 15 feet high; some have a sort of helmet of a pyramidal form; others a crown with devices; others display bushy ringlets, some with curled, and others with flowing hair; many have four hands, some six; with sceptres, shields, weapons of war, and symbols of peace. At the west end of the pagoda, there is a great dark recess, 20 feet square, totally destitute of ornaments, except the altar in the centre, and the gigantic figures which guard the several doors which lead into it. Niebuhr says these figures are eight in number; they are naked, and $13\frac{1}{2}$ feet high; their heads, decorated like the other statues, have rich collars round their necks, and jewels of great size in their ears. In the before-mentioned recess, the Lingam divinity is represented. The pagoda at Salsette exceeds that at Elephanta; the two colossal statues immediately before the entrance of the grand temple are 27 feet high; they have caps and ear-rings. There are here two hundred figures of idols; ninety of which are in and about the great pagoda. In the interior spaces, which recede from the apartments, the Lingam is represented. Many of the sculptures in these grand temples have reference to the astronomical, as well as mythological notions prevalent in India.

At Vellore, Ellore, or Ellora, (*Plates* I. and II.) the sculptures, &c. are still more extraordinary; and all are dedicated to the Lingam or Mahdew. The height of the grand pyramid is here 90 feet; the smaller ones 50 feet; the obelisk 38 feet. The elephants on each side of the court are larger than life; and there is an apartment for the bull Nundee. See Sir C. W. Mallet's paper, *Asiatic Researches*, vol. vi. p. 383.

Sir W. Jones (*As. Res.* vol. i. p. 253) is of opinion, that the Eswara and Isi of the Hindoos are the Osiris and Isis of Egypt. He says, that the word Misr, the native appellation of Egypt, is familiar in India; that Tirhoot was the country, asserted by a learned brahmin to be that in which an Egyptian colony of priests have come from the Nile to the Ganges and Yamma (Jumna). And again, in his third annual discourse, the remains of architecture and sculpture in India, prove an early connection between this country and Africa; the pyramids of Egypt, the colossal statues of the Sphinx, and the Hermis Canis, which last bears a great resemblance to the Varahavatu, or the incarnation of Vishnu, indicate the style and mythology of the same indefatigable workmen, who formed the vast excavations of Canarah, the various temples and images of Buddha, and the idols which are continually dug up at Gaya.

Kempfer asserts, that the great Indian saint, Buddha, was a priest of Memphis, and having fled to India, introduced the worship of Apis.—Kempfer's *Hist. Japan.* vol. i. p. 38, ed. 1738.

Athanasius Kircher is of opinion, that after Cambyses had murdered Apis, the most revered of the Egyptian deities, he committed wanton cruelties on the priests, and destroyed their magnificent temples, as related by Herodotus, and that the priests flying into the neighbouring countries of Asia, there propagated the superstitions of Egypt.

The lotus was anciently in Egypt, and is still in India, held sacred. Herodotus calls it the lily of the Nile. The Egyptian priests had a sacred language; so have the brahmins. The Egyptians, according to Diodorus Siculus, were divided into five tribes, of which the first was sacerdotal; the Indians are separated into four tribes, besides an inferior one, named Buzzer Sunker.

Father Loubere, who went ambassador from the king of France to the king of Siam, in 1687, thinks the superstition of Boodh no other than the Sommonacodom, or stone deity of the Siamese, originally from Egypt. He says, that their astronomers have fixed the death of Sommonacodom to the year B.C. 545, and that it was then their first grand astronomical epocha commenced. Now, according to Usher, Cambyses invaded Egypt in 525 B.C. Loubere adds, that the Siamese priests live in convents, which consist of many cells ranged within a large enclosure; that in the middle of the enclosure stands the temple; that pyramids stand near to, and quite round the temple, all within four walls.—See Loubere's *Hist. of Siam*, in Harris's *Coll. of Voy.* vol. ii. p. 482. Sir W. Jones thinks that the great statue of Narrayen, or the Spirit of God, who at the beginning floated on the waters, as that statue is now to be seen in the great reservoir of Catmander, the capital of Nepaul, is the same as the Cneph of Egypt, under a different appellation; both statues are made of blue marble.—See *Asiatic Researches*, vol. i. p. 261.

Mr. Call has published a drawing of the signs of the zodiac, which he found in the ceiling of a choultry at Verdapettah, in the Medurah country, viz., Brahma, painted in pagodas, in the act of creation, floating over the watery abyss, reclining upon the expanded leaf of lotus; and Osiris is found in the same attitude, recumbent on the same plant, in the Egyptian monuments.—Maurice, vol. ii. p. 394.

In the Hindoostan edifices, although many parts of the general arrangement and principal features resemble those of Egypt, yet simplicity has been more departed from, and circular outlines similar to those of pagodas have been introduced. The most splendid of the Indian edifices being wholly formed by excavation, may most properly be denominated sculptures; but even for this mode, abundance of originals exist in Egypt. The numerous sculptured tombs adjacent to the principal cities in the Thebaïd, are perfect examples, as far as regards excavations within the natural rock; and the gigantic colossal statues are equally so as to isolated forms.

Detail of Indian Architecture.—The city of Agra was built in the form of a crescent along the banks of the Jumna; its walls were constructed with stones of great size, hard, and of a reddish colour resembling jasper. It was four miles in extent, and consisted of three courts, with many stately porticoes, galleries, and turrets, all richly painted and gilt, and some overlaid with plates of gold. The first court was built round with arches, which afforded shade; the second was for the great omrahs and ministers of state, who had here their apartments for transacting public business; and the third court, within which was the seraglio, consisted entirely of state apartments of the emperor, hung round with the richest silks of Persia. Behind these were the royal gardens. In front of the palace, towards the river, a large area was left for the exercise of the royal elephants, and for battles of the wild beasts; and in a square which separated the palace from the city, a numerous army lay constantly encamped. Mandesto, who visited Agra in 1638, then in the zenith of its glory, says, it was surrounded by a wall of freestone and a broad ditch, with a drawbridge at each of its gates. He states, that at the farther end of the third court, under a piazza, were a row of silver pillars; that beyond this was the presence-chamber, with golden pillars; that within a balustrade was the royal throne of massy gold, almost incrusted with diamonds, pearls, and other precious stones; that above this throne was a gallery, where the Mogul appeared every day at a certain hour, to hear and redress the complaints of his subjects; and that no person but the king's sons were admitted behind these golden pillars. He mentions also an apartment remarkable for its tower, which was covered with massy gold, and for the treasure it contained, having eight large vaults filled with gold, silver, and precious stones. Tavernier, who visited the Agra near the end of the 17th century, and in the absence of the court had permission to examine the inside, describes a gallery, the ceiling of which was decorated with branched work of gold and azure, and the walls hung with rich tapestry. The gallery which fronted the river, the monarch had proposed to cover over with a sort of lattice-work of emeralds and rubies to represent grapes with their leaves when they are green, and when they begin to grow red; but this design then remained imperfect, there being only three stocks of a vine in gold, with their leaves enamelled with emeralds, and rubies representing grapes; being a specimen of what was intended for the whole.

We have been thus minute in the description of the palace of Agra, because, having been built by one of the most enlightened princes of the East, it affords a perfect specimen of the scale upon which the monarchs of those extensive and rich countries acted. And it will be allowed, that the establishments of Akbar and his great rajahs, occupying four miles along the banks of the Jumna, and connected with a handsome and prosperous city, must have produced a picture sufficiently splendid, and emblematic of the wealth and power of the prince who erected it.

At Cuttek, or Cuttack, the capital of Orissa, there is a fine palace. It consists of nine distinct buildings:—1. for elephants, camels, and horses; 2. for artillery, military stores, and quarters for the guards; 3. for porters and watchmen; 4. for artificers; 5. for kitchens; 6. for the rajah's public apartments; 7. for the transaction of private business; 8. where the women reside; 9. the rajah's sleeping apartments.

The specimens here selected being the most noted, will, we trust, convey an idea of the nature of the Indian cities and palaces; and we shall therefore proceed to consider their sacred edifices.

We have already stated, that these were of five different sorts; that is, 1. pyramids; 2. excavations; 3. square or oblong courts; 4. in the form of a cross; and 5. perfectly circular.

1. We are here at a loss to determine whether or not the construction of Indian pyramids preceded that of their excavations. To construct a pyramid of rude stones, is certainly a much simpler operation than forming a cavern ornamented with sculpture; so that although it may be conceived that mankind might, for the purposes of worship, make use of the simple plain cavern, either natural or artificial, previous to the construction of buildings of great magnitude on the surface: yet it is not very probable that the splendid excavations of Elephanta and Vellore, in which were rich sculptures, and even pyramids cut out of the solid rock, could have preceded a rude pyramid on the surface. But as the purposes to which the pyramids of Deogur and Tanjore are appropriated partake very much of the nature of the cavern, their entrance-doors being very small, their interior being lighted by means of lamps, and the middle chamber by one lamp only; there is some reason for supposing, that in places where rocky eminences were not conveniently situated, or from motives now unknown, some change of ideas taking place, these pyramids might be constructed for purposes similar to the original cavern or grotto, in the same manner as the Egyptian pyramids are considered to have been done with regard to the tombs of the Thebaïd. The external faces of the pyramids of Deogur and Tanjore are very rude.

2. In regard to excavations, they are numerous and extensive. In some instances, they are very simple and plain; in others, highly ornamented with architectural forms and sculptures. From Captain Wilson's paper in the 6th volume of the *Asiatic Researches*, we learn, that an extensive branch of the Caucasus was named by the Greeks, Parapamis, from *Para Vami*, the pure and excellent city of Vami, commonly called Bamaiya. It is situated on the road between Balkh and Cabul, where vast numbers of apartments are cut out of the rocks, some of them so large that they are supposed to have been temples. And Abul Fazel says, that in the soubah of Cashmere, in the middle of the mountains, 12,000 apartments were cut in the solid rock. At this place there were 700 places where the figure of a serpent was sculptured.

Although neither the precise form nor dimensions are given, yet from the great number of excavations, and the place being noticed by the Greeks, it must, in former ages, have been of importance, at least, for its sanctity; and its situation between India and Persia renders it still an interesting subject of inquiry.

In other parts of India, the excavated temples have fallen more frequently under the observation of well-informed scientific persons, who have, with laudable industry, furnished the public with exact representations, and full details respecting them. The three principal ones, and which our limits will only enable us to notice, are Elephanta, Salsette, and Vellore or Ellora.

Elephanta is situated near Bombay, in an island so named from the figure of an elephant being cut upon the rocks on the south shore. The grand temple is 120 feet square, and supported by four rows of pillars; along the side of the cavern are from forty to fifty colossal statues, from 12 to 15 feet high, of good symmetry, and, though not quite detached from the rock, boldly relieved; some have a helmet of pyramidal form, others a crown, decorated with jewels and devices, and others have only bushy ringlets of flowing hair; many of them have four hands, some six, holding sceptres, shields, symbols of justice and religion, warlike weapons and trophies of peace, some inspire horror, others have aspects of benignity. The face of the great bust is 5 feet long, and the breadth across the shoulders 20 feet. At the west end of this great pagoda is a dark recess, 20 feet square, totally destitute of ornament; the altar is in the centre, and there are two gigantic statues at each of the four doors by which it is entered. Niebuhr represents these statues as naked, 13½ feet high, and the sculpture good; their heads are dressed like the other statues, and they have each rich collars round their necks, and jewels in their ears. Hunter states, that, on entering Elephanta, there is a veranda or piazza, which extends from east to west 60 feet, that its breadth is 16 feet, and that the body of the cavern is on every side surrounded by similar verandas.—*Archæologia*, vol. vii. p. 287.

Canara, in the island of Salsette, which is also situated near Bombay, is represented by Linshotten, who visited it in 1759, as being like a town. He describes the front as hewn out of the rock, in four stories or galleries, in which there are 300 apartments: these apartments have generally an interior recess, or sanctuary, and a small tank for ablution. In these recesses, as at Elephanta, are representations of the Lingan deity. The grand pagoda is 40 feet high to the soffit of the arch or dome; it is 84 feet long, and 46 broad. The portico has fine columns, decorated with bases and capitals: immediately before the entrance to the grand temple are two colossal statues, 27 feet high, which have mitre caps and ear-rings. Thirty-five pillars, of an octagonal form, about 5 feet diameter, support the arched roof of the temple; their bases and capitals are composed of elephants, horses, and tigers, carved with great exactness. Round the walls, two rows of cavities are placed with great regularity, for receiving lamps. At the farther end is an altar of a convex shape, 27 feet high, and 20 in diameter; round this are also recesses for lamps, and directly over it is a large concave dome cut out of the rock. Immediately about this grand pagoda, there are said to be 90 figures of idols, and not less than 600 within the precincts of the excavations.

Mr. Grose, who visited India in 1750, seems to be of opinion, that the labour required to construct Elephanta and Salsette, must have been equal to that of erecting the pyramids of Egypt; and though it is not mentioned which of the many pyramids he refers to, the remark sufficiently expresses his admiration of the greatness of these Indian works. He observes (p. 92) that the roof of Elephanta was flat; that of Salsette of an arch-form, supported by rows of pillars, of great thickness, arranged with much regularity; that the walls are crowded with figures of men and women, engaged in various actions, in different attitudes; that along the cornice there are figures of elephants, horses, and lions, in bold relief; and above, as in a sky, genii and dewtah are seen floating in multitudes.

But magnificent as the excavations at Elephanta and Salsette must appear, they are still surpassed by those near Vellore, Ellore, or Ellora, which is situated 18 miles from Aurungabad, capital of the province of Balagate, N. lat. 19° 20′, E. long. 75° 30′.

Sir C. Mallet, in a paper he transmitted to the president of the Asiatic Society, and published in the sixth volume of their *Researches*, gives a detailed account of sixteen of them:—

1. Jagnath Subba.
2. Adnaut Subba.
3. Indur Subba.
4. Pursuram Subba.
5. Doomar Lyna.
6. Jun Wassa.
7. Comar Wana.
8. Chana, or Oil Shop.
9. Neelkunt Mahdew.
10. Ramish Wur.
11. Kylas, or Paradise.
12. Dus Outar.
13. Tee Tal.
14. Bhurt Chutturghun.
15. Biskurma, or Carpenter's Hovel.
16. Dehr Wanar, or Hallulcore's quarters.

Of these we must, of course, confine ourselves to such parts as are calculated to convey a general idea of their architecture; with this view, we have selected for engravings (*see Plates* I. and II.) the ground-plan of Kylas, the entrance and section of Biskurma, the elegant entrance to the cave of Jugnath Subba, the temple of Indur Subba, and a singularly-beautiful piece of sculpture at the door of Jun Wassa. We shall also give the description and dimensions of the Kylas and the Biskurma.

Kylas, alias *Paradise*, (aspect, west.)—This wonderful place is approached more handsomely than any of the foregoing, and exhibits a very fine front in an area cut through the rock. On the right-hand side of the entrance is a cistern of very fine water. On each side of the gateway there is a projection reaching to the first story, with much sculpture and handsome battlements, which, however, have suffered much from the corroding hand of time. The gateway is very spacious and fine, furnished with apartments on each side, that are now usually added to the dewries of the eastern palaces. Over the gate is a balcony, which seems intended for the Nobut Khanneh. On the outside of the upper story of the gateway, are pillars that have much the appearance of a Grecian order. The passage through the gateway below is richly adorned with sculpture, in which appear Bouannee Ushtbooza on the right, and Gunnes on the left. From the gateway you enter a vast area, cut down through the solid rock of the mountain, to make room for an immense temple of the complex pyramidal form, whose wonderful structure, variety, profusion, and minuteness of ornament, are too elaborate for description. This temple, which is excavated from the upper region of the rocks, and appears like a grand building, is connected with a gateway by a bridge left out of the rock as the mass of the mountain was excavated. Beneath this bridge, at the end opposite the entrance, there is a figure of Bouannee sitting on a lotus, and two elephants with their trunks joined as though fighting, over her head. On each side of the passage under the bridge, is an elephant marked (*a*) in the plan, one of which has lost its head, the other its trunk, and both are much shortened of their height by earth. There are likewise ranges of apartments on each side behind the elephants, of which those on the left are much the finest, being handsomely decorated with figures. Advanced in the area, beyond the elephants, are two obelisks (*b*) of a square form, handsomely graduated to the commencement of the capitals, which seem to have been crowned with ornaments, but they are not extant, though, from the remains of the left-hand one, I judge them to have been a single lion on each.

To preserve some order, and thereby render easier the description of this great and complex work, we shall, after mentioning, that on each side of the gateway within there is an abundance of sculpture, all damaged by time, proceed to describe the parts of the centre structure; and then, returning to the right side, enumerate its parts; when, taking the left hand, we shall terminate the whole in a description of the end of the area opposite the gateway, and behind the grand temple, exemplifying the whole by reference to the annexed plan.

Centre below.—Passing through the gateway (1) below, you enter the area (2), and, proceeding under a small bridge, pass a solid square mass (3), which supports the bull Nundee stationed above; the sides of this recess are profusely sculptured with pillars and figures of various forms. Having passed it, you come to the passage under another small bridge, beneath which there is, on one side, a gigantic figure of the Rajah Bhoj, surrounded by a group of other figures, opposite to which is a gigantic figure Guttordhuj, with his ten hands. At each end of this short passage commences the body of the grand temple (4), the excavation of which is in the upper story, that is here ascended by flights of steps on each side (5).

Right and left-hand sides of the temple below.—The right-hand side is adorned with a very full and complex sculpture of the battle of Ram and Rouon, in which Hunomaun makes a very conspicuous figure. Proceeding from this field of battle, the heads of elephants, lions, and some imaginary animals, are projected, as though supporting the temple, till you come to a projection (6), in the side of which, sunk in the rock, is a large group of figures, but much mutilated. This projection was connected with the apartments on the right-hand side of the area by a bridge (7), which has given way, and the ruins of it now fill up the sides of the area. It is said to be upwards of a hundred years since it fell.

Passing the projection of the main body of the temple, it lessens for a few paces, then again projects (8); and after a very small space on a line of the body of the temple, the length of this wonderful structure, if what is fabricated downwards out of a solid mass can be so called, terminates in a smaller degree of projection than the former. The whole length is supported in the manner above mentioned, by figures of elephants, lions, &c., projecting from the bases, to give, it should seem, the whole vast mass the appearance of movability by those mighty animals. The hindmost, or eastern extremity of the temple, is composed of three distinct temples, elaborately adorned with sculpture, and supported, like the sides, by elephants, &c., many of which are mutilated. The left-hand side (from the entrance) differs so little from the right, that it is unnecessary to be particular in mentioning anything, except, that, opposite the description of the battle of Ram and Rouon, is that of Keyso Pando, in which the warriors consist of footmen, and others mounted on elephants, and cars drawn by horses, though none are mounted on horses. The principal weapon seems the bow, though maces and straight swords are discoverable.

Centre above.—The gateway consists of three centre rooms (9), and one on each side (9). From the centre rooms, crossing the bridge (10), the ascent is by seven steps (11) into a square room (12), in which is the bull Nundee. This room has two doors and two windows. Opposite the windows are the obelisks (*b*) before mentioned.

From the station of Nundee we cross over the second bridge (13), and ascend by three steps (14) into a handsome open portico (15), supported by two pillars (above each of which, on the outside, is the figure of a lion, that, though mutilated, has the remains of great beauty; and, on the inside, two figures resembling sphinxes) towards the bridge, and two pilasters that join it to the body of the temple, the grand apartments of which (16) are entered from the portico by four handsome steps and a doorway, on each side of which are gigantic figures. Advancing a few paces into the temple, which is supported by two rows of pillars, besides the walls that are decorated with pilasters, there is an intermission of one pillar on each side, leading to the right and left to an open portico (17), projecting from the body of the temple; from the right-hand one of which, the bridge, already mentioned as broken, connected the main temple with the side apartments, to which there is now no visible access but by putting a ladder for the purpose; though I was told there is a hole in the mountain above, that leads to it, which I had not time nor strength to explore. The access from the opposite is by stairs from below. The recess (18) of the Ling (19) of Mahdew, to which there is an ascent of five steps, forms the termination of this fine saloon, on each side of the door of which is a profusion of sculpture. The whole of the

ceiling has been chunamed and painted, great part of which is in good preservation.

A door (20) of each side of this recess of the Ling of Mahdew leads to an open platform (21), having, on each side of the grand centre pyramid that is over the recess of the Ling, two other recesses (22), one on each side, formed also pyramidically, but containing no image. Three other pyramidical recesses (23), having no images within them, terminate the platform, all of them elaborately ornamented with numerous figures of the Hindoo mythology. Many of the outer, as well as the inner parts of this grand temple, are chunamed and painted. The people here attribute the smoky blackness of the painting within to Aurungzebe having caused the different apartments to be filled with straw and set on fire, which can be reconciled on no other ground than that he meant to efface obscenities, as there are many in the sculptures. Upon the whole, this temple has the appearance of a magnificent fabric, the pyramidal parts of which seem to be exactly in the same style as that of the modern Hindoo temples.

Right-hand side of the area.—This side of the rock has a continuance of excavations, as marked in the plan; but all those below, except the veranda, which I shall quit for the present, are of little note; and those above of three stories, called Lunka (24), which appear much more worthy of attention, are inaccessible but by a ladder, from the fall of the bridge. We shall, therefore, proceed to the

Left-hand side of the area.—In this side there are excavations of some consideration below, from which we ascend to an upper story, called Par Lunka, by an indifferent staircase, into a fine temple (25); at the extremity of which is a recess, containing the Ling of Mahdew; and opposite thereto, near the entrance from the staircase, is the bull Nundee, with two large fine figures, resting on maces, on each side of the recess in which he sits. The ceiling of this temple is, I think, lower than any of the foregoing. The whole of this temple is in fine preservation, strongly supported by very massy pillars, and richly ornamented with mythological figures, the sculpture of which is very fine. The ceiling, like the others, has the remains of painting visible through the dusky appearance of smoke with which it is obscured. Descending from Par Lunka, we pass through a considerable ensculptured excavation (26), to a veranda (27), which seems allotted to the personages of the Hindoo mythology (a kind of pantheon) in open compartments. These figures commence on the left hand with, 1. The Ling of Mahdew, surrounded by nine heads, and supported by Rouon. 2. Goura Parwuttee, and beneath Rouon, writing. 3. Mahdew, Parwuttee, and beneath Nundee. 4. Ditto, ditto. 5. Vishnu. 6. Goura and Parwuttee. 7. A Bukta (votary) of Vishnu, with his legs chained. 8. Goura and Parwuttee. 9. Ditto. These representations of Goura and Parwuttee all differ from each other. 10. Ditto. 11. Vishnu and Luchmee. 12. Bal Budder issuing from the Pind, or Ling of Mahdew. Here ends the left-hand side, and commences the east extremity, or end of the area (28), in which the figures are continued, *viz.*, 13. Goura and Parwuttee. 14. Behroo, with Govin Raj transfixed on his spear. 15. Dytasere on a chariot, drawing a bow. 16. Goura and Parwuttee. 17. Kal Behroo. 18. Nursing Outar, issuing from the pillar. 19. Kal Behroo. 20. Bal Behroo. 21. Vishnu. 22. Govin. 23. Brimha. 24. Luchmedass. 25. Mahmund. 26. Nunain. 27. Behroo. 28. Govin. 29. Bal Behroo. 30. Govin Raj and Luchmee. 31. Kissundass. Here ends the veranda of the eastern extremity: and we now proceed with that on the right hand (29), having in our description of that side, stopped at the commencement of this extraordinary veranda, for the purpose of preserving the enumeration of the figures uninterrupted, *viz.*, 32. Mahdew. 33. Ittuldass. 34. Dhurm Raj embracing Uggar Kaum. 35. Nursing destroying Hurn Kushb. 36. Vishnu sleeping on Seys Naug, the kummul (lotus) issuing from his navel, and Brimha sitting on the flower. 37. Goverdhun. 38. Mahdew Bullee, with six hands. 39. Krishna sitting on Gunoor. 40. Bharra Outar. 41. Krishna Chitterbooz trampling on Callea Naug. 42. Ballaju. 43. Anna Pooma. It is to be observed, that almost all the principal figures are accompanied in their respective panels by others, explanatory of the history of the idol in which it is represented.

Dimensions of the Kylas.

	Ft.	In.
Outer area, broad	138	0
Ditto, deep	88	0
Greatest height of the rock, through which the outer area is cut	47	0
Gateway, height	14	0
Ditto, breadth, without the modern building	14	4
Passage of the gateway, having on each side rooms, 15 feet by 9	42	0
Inner area or court, length from gateway to the opposite scarp	247	0
Ditto, breadth	150	0
Greatest height of the rock, out of which the court is excavated	100	0
Left Side of the Court, lower Story, viz.		
A small cave, in front two pillars, and a pilaster at each end, with three female figures buried up to the knees with rubbish, length	22	6
Ditto, breadth	8	0
Ditto, height	9	8
Another excavation, in front five pillars, two pilasters, length	57	9
Ditto, breadth, within the benches that are round this cave	6	0
Ditto, height, at the end of this is a staircase to the upper story	10	4
Interval unexcavated	20	0
Another excavation, having two large plain square pillars, and two pilasters in front, with a bench round the inside, the rock projecting beyond the pillars, length	54	6
Ditto, breadth	12	6
Ditto, height	16	0
Doorway, leading to a gallery, or veranda, 5 feet 11 inches high, by 2 feet 9 inches wide. Gallery containing figures. Length from doorway to the extreme depth of the whole excavation	117	8
Ditto, breadth	13	0
N.B. In this length are eleven pillars, each 2 feet 8 inches square.		
Ditto, height within the pillars (the projecting rock is about 3 feet lower, extending irregularly in the course of the length, from 7 to 13 feet beyond the pillars)	14	8
End of the Area, opposite the Gateway, behind the Temple.		
Whole breadth from side to side, measuring from the inner wall of the gallery on each side	186	6
Breadth of the gallery, including the pillars, there being 17 in this range	13	4
N.B. The rock projects beyond the pillars along this range, and the right hand one irregularly, from 15 to 22 feet, and is lower than the ceiling.		

Right-hand of the Court, lower Story, viz.

	Ft.	In.
Figure gallery, or veranda, of the same dimensions as the preceding parts of the same gallery, for the space of ten pillars, the angle of one being included in the foregoing; three of which were broken, it is said, to make trial of the power of the deity of the place; and when it was found that the superincumbent rock did not sink, the tempter, said to be Aurungzebe, forbore farther trial.		
Doorway, 2 feet 4 inches broad, by 5 feet high, leads to a veranda; within this veranda is a room of 60 feet by 22, and 11 feet 4 inches high. Right end unfinished: length	60	0
Ditto, breadth	17	0
Ditto, height	13	0
A small projecting room, 15 feet by 13, and 6 feet high, being choked with several finely-sculptured figures. An excavation raised 12 feet from the surface of the court, length	36	10
Ditto, depth	14	9
Ditto, height	12	0
There is a multiplicity of figures in this apartment, detached from the wall. Amongst the rest, a large skeleton figure, with a smaller one on each side. The principal is sitting, with each foot on a prostrate naked figure.		
An excavation, which has a small recess, opposite the entrance, of 6 feet by 7, and 8 high, length	24	0
Ditto, breadth	18	0
Ditto, height	10	0
An excavation terminating the lower story on the side, length	24	0
Ditto, depth	10	0
Ditto, height	11	6
Except between the two pillars, where the roof is arched, and is there 14 feet 8 inches high. This is the first instance I have seen of the arch.		

Left hand Side, upper Story, viz.

A small unfinished excavation, the dimensions of which were not worthy taking.		
Par Lunka is a fine large excavation, ascended by a flight of 25 steps, and a doorway of 3 feet 8 inches broad, by 7 feet 7 inches high; length, exclusive of the recess, in which is the temple of Mahdew	70	7
Ditto, breadth	61	9
Ditto, height	14	6
Recess, in which stands the temple of Mahdew, depth	26	0
Ditto, breadth, (the temple on the outside is 26 by 20 feet)	39	0
N.B. The whole of this apartment is full of figures, some very finely sculptured; and the centre floor is raised one foot, and the ceiling in proportion.		

Right-hand Side, first Story.

A large room, formerly connected with the grand temple by a bridge, now broken down	60	0
Ditto, depth	18	0
Ditto, height	16	0
Another room within the foregoing, entered by a door from it, having a bench all round. This inner room is very dark, having no light but from the doorway; length	36	0
Ditto, depth	29	0
Ditto, height	11	0

Right-hand Side, second Story.

	Ft.	In.
Entered by a staircase from the right side of the foregoing, of 24 steps. A large room, of the same dimensions as a correspondent one below, except two feet less in the height.		
Another room within the foregoing, depth	35	0
Ditto, length	37	0
Ditto, height	14	0
The rock seems to have given way in the centre of this room, and the rubbish has fallen in.		

Centre.

Balcony over the gateway, 14 feet by 8, and 8 high. A room within it 9 feet square, and about 9 feet high. Another within it, same dimensions. One on each side from the centre, 22 × 15 each. Bridge 20 feet × 18, with a parapet 3 feet 6 inches high. Ascent by nine steps from the bridge into a distinct room, in which is the bull Nundee, 16 feet 3 inches square. Another bridge, 21 feet × 23 broad, leading to the upper portico of the temple. This portico, with the parapet wall, is 18 feet × 15 feet 2 inches, and 17 high; within a bench that is rounded, of 4 feet high, by 3 feet 7 inches broad. This portico may be entered from the gateway, by a passage that the filling up of the rubbish has afforded; but the proper passage is by flights of steps on each side, of 36 steps each, leading up on each side the body of the temple.		

Grand Temple.

Door of the portico 12 feet high × 6 feet broad; length from the door of the portico entering the temple to the back wall of the temple	103	6
Length from the same place to the end of the raised platform behind the temple	142	6
Greatest breadth of the inner part of the temple	61	0
Height of the ceiling	17	10
Two porches on each side, measured without, 34 feet 10 inches × 15 feet 4 inches.		

The particulars of the intricate measurement of this fine temple will be best understood from the plan formed on the spot.

Height of the grand steeple or pyramid computed about 90 feet from the floor of the court, and of the smaller ones about 50; height of the obelisks about 38 feet; base 11 feet square, being 11 feet distant from each side of the room in which is the bull Nundee. The shaft above the pedestal is 7 feet square. The two elephants on each side the court or entry are larger than life." *Bishurma or Viswakurma ka Joompree.—The Carpenter's Hovel.* (Front W. 5 S.)—According to the legend, Bishurma (creator of the world, but allegorically artificer of Ram) was the artist who fabricated the whole of these wonderful works in a night of six months; but the cock crowing before they were finished, they remained imperfect, and he retired, having wounded his finger, to this hovel, in which state, the figure in front (1) of the entrance of this beautiful excavation. is said to be a representation of him holding the wounded finger; but it is more probable, that the figure is in the act of devout meditation, as many figures, with similar positions of the hands, occur. But, quitting the fable for the fact, this excavation is, in beauty, inferior to none. In form it is unique, and in design elegant. The portico is light, and striking to the beholder. On the

right hand of the entrance is a fine cistern of water Above the gateway, H, which is richly sculptured on the outside, is a balcony, which seems well suited, if not intended, for a music-gallery to the interior temple, I, which has the appearance of an elegant chapel, with an arched roof, and is exactly in the style of a similar excavation at Canara, on the island of Salsette, and another at Ekvera, near the top of Bhore Ghaut, first explored by Mr. Wales the painter. At the upper end is the figure (1) above mentioned. From the ceiling are projected stone ribs, following the curvature of the arch to the capitals of the pillars on each side, through the whole length of the excavation. Beside the grand aisle, or body of the excavation, there is a small passage formed by the row of pillars on each side round the altar; but it is dark and narrow. This singular form of a cave, wherever it has been met with, has conveyed the same impression of its being a place of congregation and adoration, rather than of residence or habitation, and has given rise to an idea, from the orbicular ceiling, and the name and attitude of its inhabitant, that it may be meant to represent the Almighty, meditating the creation of the world, under the arch or canopy of unlimited space. It is necessary, however, to accompany this idea with an acknowledgment, that the similar caves of Ekvera and Canara are not inhabited by Bishurma, they having only a very high altar, the top of which is circular, and situated, as represented in the annexed drawing, at the back of Bishurma.

Dimensions.

	Ft.	In.
Area, square	49	0
Veranda below, in front, and each side, having 12 pillars, and two pilasters, breadth	14	0
Ditto roof, height	10	4
Doorway, 4 feet broad × 8 feet four inches high; gallery above the door, square	14	0
Length of the temple from the entrance to the opposite wall behind the altar	79	0
Breadth of ditto from wall to wall	43	5
Height of ditto from the centre of the arch to the floor	35	0
N.B. The height between the pillars and wall where the ceiling is flat, is	14	10
Breadth between the pillars and wall	7	8
Circumference of pillars (two square, and 28 octagon ones)	8	1

Altar at the end, about 24 feet high.

3. The third kind of temples are those composed of square enclosures; the largest is that of Seringham, situated near Trichinopoli. The pagoda is composed of seven square enclosures, one within another; each side of the outermost is a mile in length, making the whole four miles in circumference. The walls of each enclosure are 350 feet from those of the others; they are 25 feet high, and four feet thick. Each enclosure has four gateways, that is, one in the middle of each side, opposite the cardinal points. In the outward wall, the gateway which fronts the south is ornamented with pillars, several of the single stones 33 feet long, and five feet diameter; those of which the roof is composed are still larger. All the gateways are covered with figures emblematical of their divinities. In the innermost enclosures are the chapels. Into the last, which is 1,024 feet square, and contains the sanctuary of Vishnu, no European is willingly admitted; but during the wars between the English and French, it was alternately occupied by each of the belligerents. The pagoda of Chittambrum, which consists of one square only, 1,332 feet by 396, entered by a pyramid 122 feet high, has already been described.

The pagoda Ahmed-Abad, in Guzerat, or pagoda of Santidus, consists of three courts surrounded with marble columns, and paved with marble. No person is admitted into the innermost court with sandals on. All the porticos are covered with female figures, of excellent workmanship; the inside of the roof and walls are decorated with mosaic and precious stones.—*See Tavernier* and *Thevenot's Travels* This pagoda was converted into a Turkish mosque by Aurungzebe.

The Jumna Mesgid is quadrangular, 140 paces by 120; round the inside of the enclosing wall runs a gallery, having its roof supported by 34 pillars. The temple itself stands upon 44 pillars, ranged in couples; the pavement is marble; in the middle of the front are three large gateways. On the sides are two gateways; each gate has a sort of pilasters; the minarets are Mahometan.

The pagoda of Baswara, or Bezora, now a fort, on the Vistnu river, is not enclosed by walls, but stands upon 52 lofty columns, with statues of Indian deities standing between them; it was placed in the midst of an oblong court, and surrounded by a gallery, supported by 66 pillars.—*See Tavernier.*

4. The fourth kind are in the form of a cross. The most noted is that of Benares, in the city of Casi, on the banks of the Ganges, down to which there is a flight of steps. This, from the earliest period of history, has been devoted to Hindoo religion and science. The form of the temple is that of a great cross, with a cupola in the centre, which, towards the top, takes a pyramidal form. At the extremity of each branch of the cross, which are of equal length, there is a tower with balconies, to which the access is on the outside. Within the temple, immediately under the central cupola, there is an altar, eight feet in length, and six in breadth, covered sometimes with tapestry, sometimes with cloth of gold and silver. Tavernier saw several idols, one, in particular, six feet high, having its neck decorated with a chain of precious stones; the head and neck only were visible; the body was covered with a robe. On the right of the altar was a golden figure, composed of an elephant, a horse, and a mule; upon this the deity journeyed on his guardian care of mankind. In this pagoda was also an idol of black stone, or Sammenacodom. Aurungzebe polluted this temple.

Mattra, the Methora of Pliny, eighteen miles from Agra, on the road to Delhi, is the birth-place of the beneficent god, Chreeshna. The pagoda is constructed of the same stone as Delhi, and stands upon a very extensive octagonal platform of hewn stone. This platform is ascended by two flights of stone steps, which lead to the grand portal, composed of pillars with the usual sculptures. The pagoda is in the form of a cross with a lofty cupola in the centre, and two others nearly similar on each side. The sanctuary is separated by a balustrade, behind which only priests are admitted. In the sanctuary is a square altar, 16 feet in height, covered with gold and silver brocade, and here stands the god Ram Ram; the head only is visible, and appears of black marble, with two large rubies for eyes; the body is covered with a robe of purple velvet.

5. Of those which are of a circular form, Sonnerat thinks that Juggernaut is the most ancient in India, and says that the brahmins attribute it to the first king on the coast of Orissa, 4,800 years. Its plan is a perfect circle, of immense size. Juggernaut is said to be only another name for the god Mahadeo, who is represented by the figure of a large bull, which projects out of the eastern side of the edifice; the image of Juggernaut stands in the centre of the building,

upon an elevated altar, surrounded by an iron railing. Mr. Hamilton describes the idol as being an irregular pyramidal black stone, and the temple deriving light only from one hundred lamps. He compares the edifice to a great butt set on end. This place is the residence of the arch-brahmin of all India, and the sacred dominions are said to yield pasturage for 20,000 cows.—See Buchanan's *Christian Researches*.

Besides these, which are offered as specimens of the different forms of Hindoo temples, there is one more which our general views of the matter require to be noticed. The *Ayeen Akbery* relates, that near to Juggernaut is the temple of the sun, in constructing which, the whole revenue of the Orissa was, for twelve years, wholly expended; that the wall which surrounds the whole is 150 cubits high, and 19 cubits thick; that there are three entrances: at the eastern gate are two elephants, each with a man on his trunk; on the west, are two figures of horsemen, completely armed; and over the northern gate, are two tigers sitting upon two dead elephants. In front of the gate is a pillar of black stone, of an octagonal form, 50 cubits high. After ascending nine flights of steps, there is an extensive enclosure with a large cupola, constructed of stone, and decorated with sculptures of the sun and stars, surrounded by a border, composed of a variety of human figures, some kneeling, some prostrate with their faces on the earth, and some representing minstrels, also a number of imaginary animals. But of this splendid temple, so minutely described in the *Ayeen Akbery*, not a vestige is now to be found.

It may be observed generally, that these temples, for the sake of ablution, are usually placed on the banks of the Ganges, Vistnu, or some sacred river; or where that is not the case, artificial tanks or reservoirs are constructed, generally of a quadrangular form, lined with free-stone or marble, and having steps to descend into them. Crawford mentions several tanks from 300 to 400 feet in breadth.—Crawford's *Sketches*, vol. i. p. 106. Some of these tanks cover eight or ten acres, have steps of masonry 50 or 60 feet long, are faced with brickwork, and plastered substantially and neatly. The corners of the tank are generally ornamented with round or octagonal pavilions.—*Oriental Sports*, vol. ii. page 116.

In the Birman empire, which, for situation and various circumstances connected with its history, is one of the most interesting districts of the East, the temples of Godama are of a pyramidal form, of solid brick-work, placed upon an elevated terrace; and the base of the great pyramid is frequently encompassed by a double row of small ones, having its summit terminated by an umbrella made of iron bars into a sort of filligree work, and adorned with bells; many of these pyramids are from 300 to 500 feet high. In the larger temples, the umbrella, with at least the upper part, sometimes the whole, of the pyramid, is entirely gilt. Other temples, of similar shape, are hollow, and have images of Godama within them; but the images are more frequently placed in chapels, which encompass the pyramid. Dr. Buchanan saw at Ava an image made of one block of pure alabaster, of so large a size, that one of its fingers appeared about the length and thickness of a large man's thigh and leg. The whole statue must therefore have been about fifty feet high.

At one village, Colonel Symes saw 30 or 40 yards full of statuaries, all employed in making images of the god Godama, and all in the same position, that is, sitting crossed-legged upon a pedestal: the smallest exceeded the human stature. The price of this size was 100 tackals, or 12 or 13 pounds sterling. They work the marble with a chisel and mallet, and polish with three stones of different fineness; and, lastly, by rubbing with the hand, which gives a great degree of brightness and smoothness.

At Ummapoora were spires, turrets, and lofty obelisks. The fort is an exact square, with public granaries and store-rooms, and a gilded temple at each angle, upwards of 100 feet high. In the centre of the front stands the royal palace, with a wide court in the front, beyond which is the council-hall, supported by eighty pillars, on eleven roods. The royal library is a brick building, raised on a terrace, and covered with a roof of very compound structure; it consists of one square room, with an enclosed veranda or gallery round it.—See Colonel Symes's *Embassy to Ava*, 1795.

With regard to the present practice of Hindoo architecture, we learn that in Benares, their holy city, situated on the north bank of the Ganges, 460 miles N. W. of Calcutta, the streets are so narrow as not to admit of two carriages to pass one another. The houses are built with large stones, accurately joined. Some of them are six stories high, with terraces on the summits; a band or string-course, decorated with sculpture tolerably well executed, serves to mark externally the division of each story. The windows are very small. The houses on the opposite side of the streets sometimes communicate by galleries. The number of houses built of stone and brick are reckoned at 12,000; those with mud walls 16,000. In this city there is an observatory of immense magnitude, a great number of Hindoo temples, and a spacious mosque, built by Aurungzebe, from the minarets of which, the whole city may be seen.

By the kindness of a gentleman, whose opportunities and disposition for accurate observation have qualified him to afford the most authentic information, we are enabled to give the following account of the modes pursued by the Hindoos in the construction of their dwelling-houses: "The houses of the opulent are substantially built of stone and brick, with lime mortar, generally terraced with small bricks, about four inches square, and one inch in thickness; the beams are laid about 12 feet apart, and the joints 10 inches. The masons begin to form the terrace at one angle of the building, sitting upon a plank, which is supported on the brickwork as they proceed, until they finish at the angle opposite to that at which they commenced. They have no planks upon the beams or joists to support the work below; but as the middle of the terrace (generally about 18 feet wide) is from five to six inches higher than the sides, an arch is thereby formed and supported by the surrounding walls, which are 20 inches in thickness, and have a parapet placed upon them, both for ornament and adding to the security. Over this brick arch is laid a coat or layer of jelly or gravel, or broken bricks, about the size of a large pea, mixed with quick-lime and Jaggury water; this is beat down hard with small hand mallets. Over this first coat is laid a second, composed of rough lime-mortar, which is scored across. The third and last coat is a fine chunars; and this, altogether, forms so strong and firm a body, that a whole terrace sometimes falls down entire and unbroken. Many houses are built with pointed roofs, covered with flat tiles, four inches square, and three-quarters of an inch in thickness; others have a slight coat of lime, with pantiles, which are seldom above seven inches by four; they are semicircular nearly. The houses of the middling class are usually built in a square, and covered with tiles, with a seat round the inside of the square, about three feet high, and three feet in width, protected by a veranda; it is here the inhabitants sit to receive their guests. There are no windows in the external walls, but to each house there is a small door, and frequently a window; the latter placed as high as the veranda will admit. In the open square there is generally a well, with a water-course below

the house, for domestic purposes. The houses of the poor are miserable: a few bamboos stuck in the ground, in a circular form, are collected, bent, and tied at the top, so as to represent an egg with the end cut off. They are seldom 10 feet in diameter, with a hole about three feet high to creep in at; this is shut with a leaf, tied on a simple wicker frame. The towns are generally a long street, with others at right angles, but seldom built with much regularity: some are large, some small; some are thatched, and others tiled. Those in the interior parts of the country are inferior to those near the sea-coast towns, where Europeans are settled."

From the account of Colonel Symes's embassy to Ava, we learn, that in the Birman empire, in private houses, the use of brick and stone is prohibited, and they are therefore all constructed of wood. They are raised from the ground by wooden posts or bamboos, according to the size of the building, and made tolerably convenient. The roofs are slightly covered, and at every door stands a long bamboo, with an iron hook at the end, to pull off the thatch, and another with an iron grating, to stifle the flame by pressure. Firemen constantly patrol the streets at night.

Indian Ink, a black pigment brought principally from China, and much used in architectural drawing for lining, as well as colouring. Indian Ink should be free from grit, and readily fixed, so that when used for outlines, it may not be disturbed, or run, when washed over with any other colour. A good test of the former quality is afforded by cutting the cake, or rubbing it over the teeth; but the latter can only be discovered by use.

Indian Red, a pigment introduced from India, composed of peroxide of iron. It is of a russet hue, and forms a good colour for representation of brickwork.

Indian Yellow, another Indian colour, produced from the urine of the camel. It is an excellent tint, and has the property of resisting the action of light to a greater extent than other similar colours.

Indian Rubber, the substance known by the names Indian rubber, elastic gum, Cayenne resin, cautchoc, and by the French *caoutchouc*, is prepared from the milky juice which occurs in several plants, such as the *siphonia cahuca*, *jatropha elastica*, &c. It is, however, extracted chiefly from the first plant, which grows in South America and Java. The manner of obtaining this juice, is by making incisions through the bark of the lower part of the trunk of the tree, from which the fluid resin issues in great abundance, appearing of a milky whiteness as it flows into the vessel placed to receive it, and into which it is conducted by means of a tube or leaf, fixed in the incision, and supported with clay. On exposure to the air, this milky juice gradually inspissates into a soft, reddish, elastic resin. It is moulded by the Indians in South America into various figures, but is commonly brought to Europe in that of sphere-shaped bottles, which are said to be formed by spreading the juice of the siphonia over a proper mould of clay; as soon as one layer is dry, another is added, until the bottle is of the thickness desired. It is then exposed to a thick dense smoke, or to a fire, until it becomes so dry as not to stick to the fingers, when, by means of certain instruments of iron or wood, it is ornamented on the outside with various figures. This being done, it remains only to pick out the mould, which is easily effected by softening it with water. Indian rubber may be subjected to the action of some of the most powerful menstrua, without suffering the least change, while its pliability and elasticity are eminently peculiar to itself.

INDURATING, (from the Latin *induro*, to harden) a term applied to such things as give a harder or firmer consistence to others, either by the greater solidity of their particles, or by dissipating the thinner parts of their matter, so as to leave the remainder harder.

INFIRMARY, a hospital, or house for the reception and cure of invalids.

INLAYING. *See* Marquetry, Mosaic, and Veneering.

INN, a public tavern, or lodging-house, for the entertainment of travellers, &c.

INNER PLATE, the wall-plate in a double-plated roof, which lies nearest the centre of the roof, the side of the other wall-plate, called the *outer plate*, being laid in the inner surface of the wall.

INNER SQUARE, the edges forming the internal right angle of the implement called a *square*.

INSCRIBED, (from the Latin *inscribo*, to write) in geometry, is said of a figure when all its angles touch either the angles, sides, or planes of another figure within which it is contained.

Inscribed Figure, a figure placed within another figure or solid, so that all its angles may touch either the angles or sides of it, or both.

INSERTED COLUMN, one that is let into a wall.

INSTRUMENTS, *Mathematical*, a set of implements for describing mathematical diagrams and drawings of every description, when the figures or elementary parts are composed of straight lines, circles, or arcs of circles. The most useful drawing instruments are the following:

A drawing-pen—a pair of plain compasses, commonly called *dividers*—a pair of drawing compasses, with a pen and pencil foot—a pair of bow-compasses—a pair of triangular compasses—a pair of proportional compasses—a set of spring-bows for small work, consisting of spring-dividers, spring-bow pen and bow-pencil—a protractor, in the form of a semicircle, or of a rectangle—a plain scale—a sector—and a parallel rule.

Figure 1. *Plate* I.—The *drawing-pen*. No. 1, the steel pen. No. 2, the same with a pointer, which is screwed into the upper end of the drawing-pen, and has its point enclosed in it, as in a case. The end which contains the ink consists of two thin plates, adjusted by a screw; one of the plates is movable on a joint, for the purpose of being cleaned.

Figure 12. *Plate* II.—The *dividers*. The common sort.

Figure 9, No. 2, hair dividers, in which, by means of a screw, at *a*, the slighest alteration may be made in the extent, by turning it, one way or the other, as the distance requires to be shortened or extended.

Figure 12.—The *drawing compasses*. No. 1, the crayon foot. No. 2, the ink foot. Both these feet are movable upon a joint, so that when fitted in for use, they may be brought perpendicular to the surface of the paper, and thereby perform with greater accuracy. One leg of these compasses has a cylindrical socket, with a parallel slit on the outer side, into which the upper end of each foot is closely fitted: the slit permits the leg of the compass to expand at the socket, and thereby retains the foot with the greater force, in consequence of the spring acquired by the surrounding parts of the socket in forcing in the foot.

Bow-Compasses, one of small dimensions, and were so called from the handling point in the original construction being made in the form of a bow; but which being found inconvenient for the fingers, has been altered to the present shape.

Figure 11.—A pair of *triangular compasses;* consisting of three legs, two of which are movable at the head, in the same manner as the dividers or the drawing-compasses; the third leg, which is made of steel, is fitted into a socket, through a knob projected from the side of the head, by which means

it is movable in almost any direction, while the other two remain stationary. Sometimes there is a joint in one of the legs, which permits its being lengthened or shortened at pleasure, so as to answer the expansion of the other two.

The *plain proportional compasses* are made in the form of a cross, having a parallel slit cut down the middle of each part, and a centre piece fitted to each, so as to be movable round a pin, and to slide from one end of the slit to the other, or to any intermediate distance, to admit of the two points at one end being set in any ratio to the two points at the other. The centre piece is fastened by means of a nut and screw.

Figure 10.—The *improved proportional compasses.* In these, the method of construction is in all respects the same as in the plain proportional compasses; but the adjusting screw is in addition, which admits of its being set with greater accuracy. The parts of the proportional compasses, when shut, mutually cover each other. Scales of different gradations are engraved on the margin of each part, and on both sides of the compasses, for certain uses, which will be afterwards shown.

The common *protractor* is in a semicircular form, with a scale upon one side;

Figure 11, *Plate* I.—The best kind of *protractor*, in the form of a rectangle.

Figure 12.—A *plain scale;* consisting of lines divided into equal parts, of various proportions.

Figure 13.—A *sector*, in the form of a joint rule. The figure represented is of the best kind, having a French joint.

Figure 14.—The common *parallel rule.*

Figure 15.—The rolling *parallel rule.*

The *drawing pen* is used in making ink lines by the edge of a ruler; the cavity between the plates receives the ink, which is supplied from a common quill-pen, or a camel-hair pencil; or, what is perhaps better than either, by wetting the inside of the nibs, and taking up the ink or colour with the point of the pen, by which means the ink will rise without difficulty, and free from sediment. In performing this operation, the plane of the inside of the plate should be parallel to the edge of the rule, and in a plane perpendicular to the surface of the paper.

The use of *the dividers* is to take the extent of any line or surface from one point to another, in order to transfer it to some other line; to repeat any extension upon a straight line in an equimultiple; to divide a straight line, or the circumference of a circle, or any arc thereof, into equal parts; to proportion the parts of a drawing by a scale, in any desired ratio to each other; to construct a drawing similar to one already drawn, either greater or less, by an appropriate scale to each; to construct an angle of any number of degrees; to measure the quantity of any given angle in degrees.

The *drawing compasses* are used either in describing temporary arcs, or whole circumferences, with black-lead pencil, or permanently in ink. If the diagram or drawing consist of many circles, and is to be finished in ink, the circumferences must be first drawn with a pencil, and when afterwards inked must be cleaned with Indian rubber.

The *bow compasses* are used in the description of small circles, in which the legs of the larger kind would be apt to vibrate, and thereby make the arc or circumference ragged.

The *triangular compasses* are used in transferring a given angle from one place to another; or in taking the three points of a triangle at once, and transferring them to any required place, where the figure may be completed by joining the points. These compasses, though exceedingly useful, are but little known: they are serviceable in copying all kinds of drawings, as from two fixed points the position of a third may always be ascertained.

The *proportional compasses* are used in making one drawing similar to another, without the use of scales or triangular lines; in graduating the radii of spirals; in dividing circles into any number of parts between two limits, generally from six to twenty; in dividing a straight line into any number of equal parts, from two to a certain other limit, which is generally about ten.

Some general uses of the proportional compasses may be obtained from the following examples, which, though made to particular numbers in the cases of the planes and solids, will show the application of the principle to any other number contained in the margin of the instrument.

To divide a straight line into any number of equal parts.—Set the index marked upon the centre to the number on the line of lines; then take the extent of the given line with the longer points of the instrument, and the shorter points will divide the line as required. Thus, let it be required to divide three inches, or any distance within the reach of the compasses, into five equal parts: set the index to five on the line of lines: then take three inches, or the distance required by the longer points of the compass, and the shorter points will divide the line into five equal parts.

To divide a circle into any number of equal parts, from six to twenty, that the length of the compasses will admit of.—Set the index upon the number in the line of circles, and with the longer points take the radius of the circle; then the distance between the shorter ends being repeated as chords round the circumference, the circle will be divided as required. Should it be required to divide the circle into ten parts, set the index to ten on the scale of circles, and with the longer points of the compasses take the radius of the circle, and the shorter points will divide the circumference into ten equal parts. And thus any regular polygon, from six to twenty sides, may be inscribed in a circle.

Line of Lines exemplified.

To divide a line of 5 inches into three equal parts.—Set the index to three on the scale of lines, then from any scale of equal parts take the extent of 5 between the longer legs, and the distance between the shorter will be one-third of that between the longer.

Line of Circles exemplified.

To inscribe an enneagon, or regular polygon of nine sides, in a circle.—Let the radius of a circle be 3 inches, it is required to inscribe therein an enneagon. Set the index to the ninth division, open the compasses and take the extent of the radius, 3 inches, between the longer legs; then will the distance between the shorter be a side of the required polygon. And thus for any other number marked on these compasses.

Line of Planes exemplified.

To find the square root of a given number by the proportional compasses; say, that of four.—Shut the compasses and unscrew the nut, slide the centre along the groove till the index points to the number 4 upon the line of planes. Open the compasses, and from any scale of equal parts on the plane scale, or elsewhere, take 4 between the points of the longer legs; apply the points of the shorter legs upon the same scale, and the distance between them will be equal to the square root of the distance between the points of the longer legs, which in this case is 2, the square root of the given number 4.

Likewise, if the index be set to 9, the root of 9 will be 3.

To find a mean proportion between two given numbers.—Required the mean proportion between 2 and 4½. The way to find a mean proportion between two numbers is, to multiply them together, and extract the square root of the product. Therefore open the compasses with the index set against 9,

as 64 to 1; that is, the architect can vary the size of his structure in the ratio of 64 to 1, in seven different elevations.

The last line on the common plain scale is that of chords; and is much more used than the protractor for laying off or measuring any proposed angle. Thus, let it be required to draw the line B C, *Figure* 19, to make an angle of 35° with the line A C. To do this, set one point of the compasses in the beginning of the line of chords, and extend the other to 60; with that extent, as a radius, place one foot in C, and with the other describe the arc A B; then take from the chords 35° in the compasses, and set them on the arc from A B; then through C and D draw C B, and it is done.

Again,—If it be required to measure any angle, as A B C, *Figure* 20, produce B A, if necessary; take 60° from the chords in the compasses, and with one foot in B describe the arc A C, cutting the leg B A at A, and B C at C; then take the arc A C in the compasses, and applying it upon the beginning of the line of chords it will reach to 30°, the quantity of the angle required. But the line of chords is more useful on the sector, to which we now proceed.

N.B.—The construction of this line is shown in the next article.

The *sector* is a most useful instrument, as forming a universal plane scale.

The lines commonly laid down upon the sector, are—a line of equal parts, marked L at the end; a line of chords to 60°, marked C; a line of sines, to 90°, marked S; a line of tangents, to 45°, marked T; another line of tangents from 45 to 75 or upwards, marked *t a*; a line of secants, marked *s e*; a line of polygons marked P O L.

Besides these, when the sector is quite opened, there are placed on one side—a Gunter's line of artificial numbers, *n*; a line of artificial sines, *s*; and a line of artificial tangents, *t*. Likewise a line of 12 inches, and another of the foot divided into 1000 equal parts, placed by it, for the purposes already mentioned.

Before a proper idea can be formed of these sectoral lines, and their uses, their construction must be shown from the circle. Therefore, let A C B, *Figure* 21, be a quarter of a circle, divided into 90°, described with the radius C A, on the centre C; let A E and C F be perpendicular to A C, at A and C; then if the radius A C be divided into 10, 100, 1000, &c., equal parts, it will be the line so called upon the sector.

If from A, a line be drawn to any part or division of the quadrant, as G, at 60°, then that line A G is the chord of that arc, or of 60°. And if the line A B be drawn, it will be the chord of 90°; and by setting one foot of the compasses in A, and extending the other to the several divisions, 10, 20, 30, 40, &c., they may be transferred from the circle to the line A B, which will then be properly divided into a line of chords in 10, 20, 30, 40, &c., to 90 as on the plane scale.

If from any point, G, in the quadrant, you let fall a perpendicular, G I, to the radius A C, or G H to the radius C B, then the line G I is called the sine of the arc A G; and the line G H is the sine of the arc G B, the complement of A G to 90°. And if all the divisions of the quadrant were transferred to C B by lines parallel to A B; then the line C B will be divided as a line of sines in the points, 10, 20, 30, 40, &c., to 90°.

By laying a rule from the centre, C, to the several divisions of the quadrant, 10, 20, 30, &c., it will cut the line A E in the points 10, 20, 30, &c., which will be thereby divided into a line of tangents; and here it must be observed, that the line of tangents, T, on the sector, extends but to 45°, equal to C A or C B radius; and that the line of lesser tangents, *t*, are projected from a lesser radius, and begin from 45° at the distance of its radius from the centre of the sector.

By drawing the line C L through the division 60° to the line A E, it makes A L the tangent of 60°, and C L the secant of 60°, or of the angle A C L. And if one foot of the compasses in C, the other is extended to the several divisions in the line A E, and transfer them to the line C F, then will the part B F be thus divided into a line of secants; being placed at the distance of the radius C B, from the centre of the sector, and beginning at B, where the radius ends.

It may be of use in many cases to observe, that the chord 60°, A G, is equal to the radius C A or C G; that the sine 60°, G I, besects the radius A C in I, and therefore the sine G H of 30° is equal to half the radius, or C I. Therefore the secant, C L, of 60° is equal to twice the radius, A C; for C I is to C G as C A to C L, and consequently the cosine is to radius as radius to the secant. Also, the tangent A L is to radius A C as radius B C is to the co-tangent B K.

From what has been said, the reason appears why the line of lines (or equal parts L) terminates upon the sector at 10; the line of chords, C, at 60°; the line of sines, S, at 90°; the larger tangents, T, at 45°; and that the lesser tangents, and also the secants are, of indefinite lengths.

From the nature of the sector, consisting of two pairs, or legs, movable upon a central joint, it is requisite that the lines should be laid on the sector by pairs, *viz.*, one of a sort on each leg, and all of them issuing from the centre—all of the same length, and every two containing the same angle. We shall now illustrate the nature of working problems by the sector, as follows, by the lines of lines, or equal parts L L.

Figure 22.—Let C L, C L, be the two lines of lines upon the sector, opened to an angle, L C L; join the divisions 4 and 4, 7 and 7, 10 and 10, by the dotted lines *a b*, *c d*, L L. Then by the nature of similar triangles, C L is to C *b* as L L to *a b*; and C L is to C *d* as L L to *c d*; therefore *a b* is the same part of L L as C *b* is of C L. Consequently, if L L be 10, then *a b* will be 4, and *c d* will be 7, of the same parts.

And hence, though the lateral scale C L be fixed, yet a parallel scale, L L, is obtainable at pleasure; and therefore, though the lateral radius is of a determined length in the lines of chords, sines, tangents, and secants, yet the parallel radius may be had of any size required, by means of the sector, as far as its length will admit; and all the parallel sines, &c. peculiar to it; as will be evident by the following examples in each pair of lines.

Example I.—*In the lines of equal parts.* *Figure* 22. Having three numbers given, 4, 7, 16, to find out a fourth proportional To do this, take the lateral extent of 16 in the line C L, and apply it parallel-wise, from 4 to 4, by a proper opening of the sector; then take the parallel distance from 7 to 7 in the compasses; and applying one foot in C, the other will fall on 28 in the line of lines, C L, and is the number required; for as 4 is to 7 so is 16 to 28.

Example II.—*In the line of chords.* *Figure* 23. Suppose it required to lay off an angle, A C B, equal to 35°; then with any convenient opening of the sector, take the extent from 60 to 60 and with it, as radius, on the point C describe the arc A D indefinitely; then in the same opening of the sector take the parallel distance from 35° to 35°, and set it from A to B in the arc A D, and draw A B, which will make the angle at C as required.

Example III.—*In the lines of sines.* *Figure* 24. The lines of sines, tangents, and secants, are used in conjunction with the lines of lines in the solution of all the cases of plain trigonometry; thus let there be given in the triangle A B C, the side A B = 230, and the angle A B C = 36° 30′, to find the side A C. Here the angle at C is 35° 30′; then take the lateral distance 230 from the line of lines, and make it a parallel from 53° 30′ to 53° 30′ in the line of sines; then the

parallel distance between 36° 30′ in the same lines, will reach laterally from the centre to 170.19 in the line of lines for the side A C required.

Example IV.—*In the lines of tangents.* If, instead of making the side B C radius, as before, A B be made radius; then A C, which before was a sine, will be the tangent of the angle B; and, therefore, to find it, the lines of tangents must be used thus:—Take the lateral distance, 230, from the line of lines, and make it a parallel distance on the tangent radius, *viz.*, from 45° to 45°; then the parallel tangent from 36° 30′ to 36° 30′, will measure laterally on the line of lines, 170.19, as before, for the side A C.

Example V.—*In the lines of secants.* In the same triangle, in the base A B, and the angles at B and C given, as before, to find the side or hypothenuse B C. Here B C is the secant of the angle B. Take the lateral distance 230 on the line of lines, make it a parallel distance at the radius, or beginning of the lines of secants; then the parallel secant of 60° 30′ will measure laterally on the line of lines 287.12, for the length of B C, as required.

Example VI.—*In the lines of sines and tangents conjointly. Figure* 25. In the solution of spherical triangles, use the line of sines and tangents only, as in the following example. In the spherical triangle A B C, right-angled at A, there is given the side A B = 36° 15′ and the adjacent angle B = 42° 34′ to find the side A C. The analogy is, as radius is to sine of A B, so is tangent of B to tangent of A C; therefore make the lateral sign of 36° 15′ a parallel at radius, or between 90 and 90; then the parallel tangent of 42° 34′ will give the lateral tangent of 28° 30′ for the side A C.

Example VII.—*In the lines of polygons. Figure* 24. It has been observed, that the chord of 60° is equal to radius, and 60° is the sixth part of 360°; therefore, such a chord is the side of a hexagon, inscribed in a circle. So that in the line of polygons, if the parallel distance between 6 and 6 be made the radius of a circle, as A C, and the parallel distance between 5 and 5 be taken and placed from A to B, the line A B will be the side of a pentagon A B D E F, inscribed in the circle. In the same manner may any other polygon, from 4 to 12 sides, be inscribed in a circle, or upon any given line A B.

Of Gunter's lines.—Having thus shown the use of all that are properly called *sectoral lines*, or that are to be used sectorwise, it only remains to describe another set of lines usually put upon the sector, which will in a more ready and simple manner give the answers to the questions in the above examples; these are called *artificial lines* of numbers, sines, and tangents, because they are only the logarithms of the natural numbers, sines, and tangents, laid upon lines of scales; this method was first invented by Mr. Edmund Gunter, and the lines are called *Gunter's lines*, or *the Gunter*. Logarithms are a set of numbers, so contrived, that, by addition and subtraction, the answers to all questions in multiplication, division, proportion, and the analogies of plain and spherical trigonometry, are found. Therefore, in the compasses, the extent, or ratio, between the first and second terms will always be equal to the extent, or ratio, between the third and fourth terms; consequently, if with the extent between the first and second terms, one foot of the compasses be placed on the third term, the other foot, on turning the compasses about, will fall on the fourth term sought.

Thus, in *Example* I., of the three given numbers 4, 7, and 16, take the extent from 4 to 7 in the compasses, then place one foot in 16, and the other will fall on 28, the answer, in the line of numbers, marked *n*.

Again, the artificial line of numbers and sines are used together in plain trigonometry, as in *Example* III., where the two angles B and C, and the side A B, are given; for here, if the extent of the two angles 53° 30′ and 36° 30′ be taken in the line of sines, marked *s*, and one foot be placed upon 230 in the line of numbers, *n*, the other will reach to 170.19, the answer.

Also, the line of numbers and tangents are used conjointly, as in *Example* IV.; thus, take in the line of tangents, *t*, the extent from 45°, radius, to 36° 30′, and it will reach from 230 to 170.19, the answer, as before.

Lastly, the artificial lines of sines and tangents are used together in the solution of spherical triangles.

Thus, *Example* VI. is solved by taking in the line of sines, *s*, the extent from 90°, radius, to 36° 15′, and in the line of tangents, *t*, it will reach from 42° 34′ to 28° 30′, the answer required.

It may be farther observed, that each pair of sectoral lines contains the same angle, viz., six degrees in the common six-inch sector; therefore, to open these lines to any given angle, as 35°, for instance, take 35° laterally from the line of chords, and apply it parallel-wise from 60° to 60° in the same lines, and they will all be opened to the given angle 35°.

If to the angle 35° be added the angle 6°, which they contain, the sum is 41°; then take 41° laterally from the line of chords, and apply it parallel from 60 to 60, then will the sides or edges of the sector contain the same angle, 35°. In this case, the sector becomes a general *recipe-angle*, which is an instrument for taking the quantity of any angle contained between two inclining planes.

INSULAR, or INSULATED BUILDINGS, such as stand alone.

INSULATED COLUMN, or DETACHED COLUMN, a column that stands quite clear of a wall, and may be seen all round.

INTAGLIOS, (Italian,) the carved work of an order, or of any part of an edifice.

INTAVOLATA. *See* CYMATIUM.

INTERCEPTED AXIS, the same as ABSCISSA.

INTERCOLUMN, (from the Latin *inter*, between, and *columna*, a column,) the open area between two columns.

INTERCOLUMNIATION, the distance between columns, measured by their lower diameters. Under the article COLONNADE will be found the several names given to certain distances measured by the diameter. The general distance used by the Greeks in the Doric order was that of the monotriglyph, though in the Doric portico or temple of Augustus, and the portico of Philip, king of Macedon, in the island of Delos, they are ditriglyphs. Also, on account of the triglyphs being placed in the angles of the Grecian-Doric, the extreme intercolumniation will be something less than those of the intermediate columns: as otherwise, if all the intercolumns were equal, each extreme intertriglyph would be broader than the intermediate ones.

INTERDENTILS, the space between dentiis. It appears, not only from a comparison of the most celebrated examples in the Ionian antiquities, with that of Jupiter Stator at Rome, but upon the average, that the Romans set their dentils nearer together than the Greeks, and that the dentils themselves, among the former, are of a more trifling character. In the temple of Bacchus at Teos, the space between the dentils is two-thirds of the breadth of the dentil. In the temple of Minerva Polias, at Priene, the space is nearly three-fourths of the breadth. In the temple of Jupiter Stator, which has the boldest entablature of all the Roman examples, the space is about half the breadth of the dentil; and in most other examples in which dentils are to be found, generally less.

INTERDUCES. *See* INTER-TIES.

INTER-FENESTRATION, (from the Latin, *inter*, between, and *fenestra*, a window,) the space between windows.

INTER-JOIST, the space between joists, which may be a foot between centre and centre in good buildings, and in slight houses from 18 to 22 inches.

INTERIOR ANGLE, an angle within any figure, formed by two straight-lined parts of the perimeter, or boundary of the figure; the exterior angle being that which is formed in producing a side of the perimeter of the figure. The exterior and the interior angle of any figure are equal to two right angles, and all the interior angles of any figure amount to twice as many right angles, with four, as the figure has sides: for the figure may be divided into as many triangles as it has sides, by drawing lines from all the angles to a point within the figure. And as the angles of every triangle are equal to two right angles, there will be as many times two right angles as the figure has sides; but as four of these right angles are round the point to which the lines were drawn, consequently all the internal angles of any straight-lined figure are equal to twice as many right angles, wanting four, as the figure has sides. This is only deduced as a corollary from the 32nd Proposition of Euclid, book I., where it is proved, that if the side of a triangle be produced, the exterior angle will be equal to the two interior and opposite angles, and the three angles of every triangle will be equal to two right angles.

Interior Angle is also applied to the two angles formed between two parallels, by a line cutting them on each side of the intersecting line.

Interior and Opposite Angles, an expression applied to the two angles formed by a line cutting two parallels.

Interior Polygon. *See* Polygon.

INTERMITTING, anything which destroys the continuity of another.

INTER-MODILLION, the space between modillions.

INTERNAL ANGLE. *See* Interior Angle.

Internal Angle of a Solid, the inclination of two planes, of which their line of concourse recedes; that is, if a point be taken in each plane, the straight line joining the two points will be without the solid.

INTERPENSIVÆ, (Latin,) in ancient architecture, are supposed to be cantalivers, formed by the ends of joists. *See* Vitruvius, book vi. chap. 3.

INTER-PILASTER, the space between two pilasters.

INTER-QUARTER, the space between two quarters.

INTER-TIES, or Interduces, horizontal pieces of timber, placed between upright posts, to tie or bind them together. They are used in roofing, partitioning, and walling, with timber frames for lath and plaster, or panelled brick-work.

INTRADOS, the under curved surface or soffit of an arch; generally cylindrical or cylindroidal.

INVENTION, (French,) the act of finding anything new, or a thing found; the discovery of a principle, or a new application of a principle already known, in performing certain kinds of motion or construction; contriving instruments or machines for the performance of some useful purpose. Design is very nearly allied to invention, but is commonly applied to a new combination, or new order of things already known.

Invention is of real use; but design is altogether fanciful, though productive of pleasing forms. In invention, we can reason why a principle or thing contrived will answer its intended purpose; not so in design, where the only power of judging of the effects of combination arises from previous experience of things of the like nature. In design, all the simple forms are already known; thus, from a few kinds of moulding, already known, an unlimited variety of cornices, capitals, and imposts, may be contrived or designed. In a building, all the simple forms exist in squares, circles, and other geometrical figures and solids, already known: but, from the combination being unlimited, an effect may be produced different from anything that has ever before existed.

INVERTED ARCHES, such as have their concavity or intrados below the centre or axis. They are useful in every part of a wall which is lower than the two adjacent parts, or where an interruption is made by an aperture near its base. *See* Foundation.

INVOLUTE. *See* Evolute.

INWARD ANGLE, the re-entrant angle of a solid: they are framed in recesses. *See* Internal Angle of a Solid.

ION, son of Xuthus, and grandson of Hellen, king of Phthiosis, in Thessaly. He led a colony of Greeks into that part of Asia Minor, which from him obtained the name of *Ionia*, where the Ionic order first originated. The account given by Vitruvius of the invention of this order will be found in the next article.

IONIC ORDER, the second order of architecture, in point of time, among the Greeks. When the novelty of the Doric order had abated, the desire of producing something new soon led the way to the invention of another species; and in erecting the temple of Diana, they sought a new order from similar traces, imitating the proportion and dress of women. The diameter of the columns was made an eighth part of their height; the base with folds, representing the shoe; the capitals with volutes, in form of the curled hair worn upon the right and left; and the cymatium, for the locks pending on the forehead from the crown. This new order they called *Ionic*, after the name of the country in which it was invented.

Such is the account given by Vitruvius, but it will scarcely obtain credit in the present day. Many other suggestions have been substituted, with more or less reason; but how the order originated must ever remain a matter of conjecture. Some maintain that the idea of the capital was suggested by the curls of a lady's hair, as Vitruvius; others, by the horns of rams slain for sacrifice; others, by the use of twigs placed upon the capital; and others, who adhere to the notion of Vitruvius respecting the model wooden hut, suppose the same idea to have arisen from the splitting and bending, or curling downwards, of the tops of the wooden props, under the weight of the roof-timbers. Others, again, suppose the order to have arisen naturally from the Doric, but these do not pretend to account for the origin of the capital, which forms the most striking and distinctive feature, and on the pre-existence of which all their theory depends. Having found a fair type of the Grecian-Doric in some of the edifices of Egypt, we may naturally look to that quarter for the origin of the Ionic, but we cannot say that we meet with anything very satisfactory in this quarter. It is true, we have some approach to the form of the Ionic capital in some Egyptian buildings; we find, for instance, the volutes arranged in a somewhat similar manner, though in larger numbers, yet we cannot say that the resemblance is so striking as to satisfy us as to their identity. Again, we have in the same country capitals composed of the heads of Isis, with the curls of the head-dress hanging down at each corner of the capital, and this ought almost to satisfy some who rest content with the Vitruvian fables, but we fear not others. The capitals which bear the greatest resemblance to the Ionic, are found amongst the ruins of Persepolis, where the volutes are introduced in a very similar manner, although there is more than two such volutes in each capital. The Greeks were well acquainted with the Persians when the

Ionic order was introduced, and we would suggest this as a not unlikely account of the origin of the order; but this, like all the other suggestions, fall far short of satisfaction.

In this order, the capital becomes the chief characteristic, which is sufficient to distinguish it from any other, although from the preceding or Doric order it is distinguishable by many other marked differences, such as the employment of a distinct base; the much-altered proportions; the increased number and different contour of the flutes, and the introduction of the fillets; the increased ornamentation of the entablature; and by many other variations.

The Ionic capital has not all its sides similar, the similar sides being arranged in pairs, of which two, which may be termed the faces, are ranged parallel to the architrave; and two others, at right angles to the face, and underneath the architrave, which may be called the sides. Spiral bands or volutes, as they are called, ornament each side of the face, and are connected together by a band passing across the upper portion of the face. The volutes, in fact, may be said to be formed by a band passing over the top of the shaft, and curled up at each extremity on either side of the shaft. The band being of the same width of the column, would naturally form a cylindrical roll on each side, and thus may be supposed to have been formed the baluster side of the capital. These balusters, however, are not perfectly cylindrical, but hollowed out both vertically and horizontally, and, if we continue our simile, we may suppose the band composed of some compressible or yielding mass, and the roll to be tied up tightly in the middle, so as to make the intermediate sections of the roll gradually to diminish both ways towards the middle. Otherwise, we may suppose the balusters to represent two tubes or horns, so placed together that the larger ends, or mouths, are at the greatest distance from each other, and abut against the back of the volutes. This arrangement gives the balusters a much lighter appearance, which is considerably enhanced by their being usually decorated with carving.

The face of the capital measured across the volutes is about a diameter and a half, or 90 minutes, equal to the diameter of the base; the whole width is divided into three parts, of which one is given to each of the volutes. The volutes are composed of spiral mouldings, which make several revolutions, and gradually approach closer to each other, as they near the centre, or what is termed the eye of the volute, where they cease.

In the capitals of the Athenian examples of the Ionic, and in that of Minerva Polias at Priene, the lower edge of the canal between the volutes is formed into a graceful curve, bending downward in the middle somewhat like a festoon, and revolving round the spirals which form the volute upon each side. In the temple of Erechtheus, and of Minerva Polias at Athens, each volute has two channels, formed by two spiral borders, and a spiral division between them. The border which forms the exterior of the volute, and that which forms the under side of the lower canal, leaves a deep recess between them, which continually diminishes in its breadth till it is entirely lost when it comes in contact with the side of the eye.

In the temple of Bacchus at Teos, the great theatre at Laodicea, and in all the Roman examples of the Ionic, the channel connecting the two volutes is not formed with a border on the lower edge, but is terminated with a horizontal line, which falls a tangent to the curve of the spiral at the commencement of the second revolution of each volute. *See* SPIRAL and VOLUTE.

In the example of the temple of Erechtheus, the column is terminated with a fillet and astragal a little below the edges of the volutes, and in that of Minerva Polias in the same manner, with a single fillet; and the colorino or neck of each is charged with a beautiful succession of woodbines, alternately disposed. The upper annular moulding of the column is of a semicircular section, and embellished with a rich guilloche. The echinus, astragal, and fillet, are common to both Grecian and Roman Ionic capitals, and the echinus is uniformly cut into eggs, surrounded with angular-sectioned borders, and with tongues between every two borders. The astragal is formed into a row of beads, with two small ones between every two large ones. These mouldings are cut in a similar manner in all the Roman buildings, except the Coliseum, and what relates to the taste of the foliage.

The necking of the capital is, however, frequently omitted; and the mouldings immediately under the band that connects the volutes, are thus disposed: first, a carved convex moulding, to which succeeds the enriched echinus or ovolo, and below that a bead or some other small mouldings. The abacus is square in plan, and its profile is that of a cyma-reversa or ogee-moulding, either enriched or plain, according to the richness of the capital.

When columns are introduced in the flanks of a building as well as in the front, one of the capitals of each angular column is made to face both the contiguous sides of the building, with two volutes, one upon each side projecting the two adjacent volutes by bending them in a concave curve towards the angle; as in the temple of Bacchus at Teos, of Minerva Polias at Priene, of Erechtheus, and that on the Ilissus at Athens, as also that of Fortuna Virilis at Rome. The capitals of all the columns are sometimes made to face the four sides of the abacus alike on each side, as in the temple of Concord at Rome, from which example the Scamozzian capital was formed.

A curious and probably very ancient specimen of the angular disposition of the volutes, occurs at the temple of Apollo at Bassæ, in which the capital presents four similar faces, and so far agrees with the more modern Scamozzian capital, from which, however, it widely differs in other respects. Each face of this capital is arched vertically as well as horizontally, as it curves downwards on each side from the middle of its upper edge, as well as outwardly to form the angular volutes.

This example offers other remarkable points of difference, more especially in the construction of the base, which is of very simple form, and consists of an annular moulding above a very large one of a concave profile, which spreads out beneath to considerably more than two upper diameters of the shaft.

The base employed in the Athenian Ionics consists of two tori, and a scotia or trochilus between them, and two fillets, each separating the scotia from the torus above and below: the fillet above the torus generally projects as far as the extremity of the upper torus, and the lower fillet beyond the upper torus; the scotia is very flat, and its section an elliptic curve, joining the fillet on each side: the tori and scotia are nearly of equal heights; in the Ionic temple on the Ilissus a bead and fillet were employed above the upper torus, joining the fillet to the scape of the column; the upper torus of the basis of the same temple, and that of the basis of the temple of Erechtheus, are both fluted, preserving the lower part, that joins the upper surface of the fillet above the scotia, entire. The upper scotia of the temple of Minerva Polias is enriched with a beautiful guilloche. The lower torus of the base of the antæ of the temple of Erechtheus is reeded, and that of the base of the antæ of the temple of Minerva Polias fluted, and separated from each other by two small cylindric mouldings of a quadrantal section, having their convexities joining each other. This form of a base is, by

Vitruvius, very properly called the *Attic base*, being invented and employed by the Athenians in all their Ionics. It was also adopted by the Romans, and seems to have been their most favourite base: for it is not only employed in all the examples of this order at Rome, but most frequently in the Corinthian and Composite orders also. However, the proportions of the Attic base as employed by the Romans, are different from that employed by the Greeks, the upper torus of the former being always of a less height than the lower one, both tori plain, and the scotia containing a much deeper cavity. The proportion of the bases of the Ionic and Corinthian orders on the Coliseum, the Ionic on the theatre of Marcellus, and that on the temple of Fortuna Virilis at Rome, have nearly that assigned by Vitruvius. The Ionic bases, as employed in the temple of Minerva Polias at Priene, and in that of Apollo Didymæus, near Miletus, consist of a large torus, three pair of astragals, and two scotiæ, inverted in respect of each other. The upper pair of astragals is disposed below the torus, and the scotiæ separate each pair of astragals. In the temple of Minerva Polias, an astragal is employed above the torus, separating it from the shaft; the torus itself is formed elliptically, and the under part of it is fluted: it has also a flute cut in the upper part, near to the bead. In the temple of Apollo Didymæus, the upper torus is of a semicircular section and plan, and each bead of every pair is separated by a narrow fillet. The base of the Asiatic examples differs little from that which Vitruvius appropriates to this order. In the former, the scotiæ are inverted, which gives a greater variety in the profile than when both stand in the same position as in the Vitruvian base.

The Ionians, besides the base which they appropriated to this order, sometimes used the Attic base also, as in the temple of Bacchus at Teos. This base seems not only to have been the most favourite one among the ancients, but is likewise so among the moderns. It is not so heavy in the upper part as that denominated Ionic; its contour is pleasing, and its general appearance elegant.

The shaft is fluted as in the Doric, from which, however, it differs in this, that the number of flutes is increased to 24, and their junctions are not formed by sharp arrises, but by fillets. The channels being thus multiplied, and set apart from each other, are consequently much narrower than those of the Doric order, and are much deeper in proportion to their breadth; and their extremities terminate in the semicircle, or semi-ellipse.

The architrave of the temple by the Ilissus consists of one broad facia, and its crowning cymatium; the parts of the cornice, as seen in front, are the corona, including its cymatium and sima. The capital or cymatium of the frieze, is wrought under the cornice, and consists of a sima-reversa and bead below it. The height of the architrave is about two-fifths of the entablature; and by dividing the upper three-fifths again into five parts, the plain part of the frieze will occupy three parts, and the cornice two parts.

In the Ionic order of the temple of Erechtheus, and of the temple of Minerva Polias, the architrave consists of three faciæ and cymatium; the cymatium of the frieze is mostly wrought under the corona. If the height of the entablature from the bottom of the lower facia to the top of the cymatium of the corona be divided into nineteen parts, the architrave and the part of the frieze that is seen, will each be eight parts; and the corona, including the larmier and cymatium, the other three parts. The volutes of the capitals of these orders, both for singularity and beauty, exceed every other remain of antiquity.

The Asiatic orders differ greatly from the Attic. In most of the remains of this order, as represented in the *Ionian Antiquities*, the friezes are all wanting—except in one example, and consequently the whole height of the entablatures of those without the friezes cannot be ascertained, though the architraves and cornices belonging to each other have been accurately measured. The one which has the entire entablature belongs to the great theatre at Laodicea; the frieze is pulvinated, and is something less in height than one-fifth of that of the entablature. The architraves of the temple of Bacchus at Teos, and the temple of Minerva Polias at Priene, are each divided into three faciæ below the cymatium. In all the Asiatic examples, the crowning moulding is constantly a sima-recta of a less projection than it has height: the dentils are never omitted, and their height is nearly a mean proportion between the height of the sima-recta and that of the larmier, corona, or drip, being always greater than the height of the corona, and less than that of the sima-recta. The cymatium of the denticulated band is wrought almost entirely out of the soffit of the corona, or recessed upwards, and consequently its elevation is almost concealed. The height of the cornice from the top of the sima to the lower edge of the dentils is equal, or very nearly so, to that of the architrave. The altitude of the frieze without its cymatium, or upper mouldings, may be supposed to be about a fourth part of the whole entablature; for if higher than this, the entablature would be too great a portion of the columns for any analogy we are acquainted with. In point of beautiful proportions and elegant decorations, the entablatures of these two last examples exceed every other remain; and though their proportions are very different from those remaining at Athens, they are still pleasing.

In all the Grecian examples of the Ionic order, there seems to be a constant ratio between the upper part of the cornice from the lower edge of the corona upwards, and the height of the entablature; this is nearly as 2 to 9. If these members were regulated in any other manner, their breadths would be so variable as sometimes to be so diminutive that their forms could not be perceived, and at other times so enlarged as to overcharge the whole when viewed from a proper station. Indeed the great recess of the mouldings under the corona, makes this a very distinct division, and on this account the cornice never appears too clumsy, though the whole denticulated band and cymatium of the frieze are introduced below it, which seems to be the reason of so great an apparent difference between the Asiatic and Attic species. This order, as found in the Ionian territory, is complete; but those at Athens are deficient, from their want of the dentil band, though beautiful in many other respects.

The following account of some of the more noted specimens of Ionic building, still remaining, is extracted from a series of lectures which have been published in the *Builder*.

"The earliest specimen of which any remains are to be found is the celebrated temple of Juno at Samos, which, in the age of Herodotus, was considered as the largest and most stupendous edifice ever raised by Grecian art. This interesting ruin, although often visited, has never, until recently, received any architectural elucidation. It was built about the 60th Olympiad by Rhacchus and Theodorus, two natives of the island; and the style possessing many peculiarities is such as strongly to denote its archaic origin. The bases of the columns are remarkable from the number and complication of their parts; the shaft is not fluted, nor is there any appearance of volutes to the capitals."—(Lord Aberdeen's *Inquiry*, p. 160.)

But the purest and best known specimens are to be found at Athens, where we see at once the simplest and richest modes of employing the style. The former is to be seen in

the graceful little temple on the Ilissus, and the latter in the double temple, erected in honour of the Virgin-goddess and Erechtheus. Nothing can be more simple than the design of the former beautiful little building, which is only 20 feet high to the cornice; from the fewness of the mouldings and their freedom from enrichment, it serves as a model for most of the Ionic porticos of the present day, as it is admirably adapted to domestic structures. This temple had a portico of four columns at each end, but was without any lateral columns: the columns are only 21 inches in diameter, and are eight diameters high. The architrave has only one face; and the frieze was probably also plain, although Stuart considers that it may have had an enrichment, as a fragment of sculpture representing several figures, was found at Athens, which exactly fitted the space. The cornice is composed of the fewest possible mouldings, which, throughout the building, are of the simplest character. A more enriched example is that of the temple of Minerva Polias (so called from πολις a city; thus the goddess was emphatically the protectress of the city of Athens) placed in the acropolis, at a distance of 150 feet from the Parthenon. This temple is connected with two other buildings—the Erechtheum and the Pandrosium.

We now proceed to notice this triple temple more in detail, for which purpose a plan is essential. Elevated on three steps is a portico of 6 columns, leading to what is called by Stuart the temple of Erechtheus, but which is considered by others to be the cella of the goddess. The columns are 2 feet 3 inches in diameter, 21 feet 7 inches high, including base and capital, and are 4 feet 8 inches apart. The width of the cell is 32 feet 4 inches, and its depth 23 feet 11 inches. In the rear of the cell, and divided from it by a wall, is the apartments which Stuart ascribes to Minerva, receiving its light from three openings like windows (a rare and valuable example) placed between half-columns, and having on one side a communication with the Pandroseum, and on the other with a noble portico of four columns in front, having a projection of two inter-columns. These three last-named parts are on the same level, which is, however, about 9 feet lower than that of the hexastyle portico. The columns of the tetrastyle are 2 feet 9 inches in diameter, and 25 feet in height. The little building, the Pandroseum, had six female figures, called Caryatides, instead of columns, to support the entablature, and their origin has given rise to much discussion.

There are but few examples of this order as practised by the Romans, remaining entire; amongst them are the theatre of Marcellus, the temple of Concord, and that of Fortuna Virilis. Several portions of the order have, however, been discovered in those buildings which were erected after the decline of the empire, such portions having been plundered from more ancient buildings, to enrich the new edifices. Although some of these Roman examples are of considerable merit, they would seem to fall far short of the Grecian in taste and elegance. The capital was greatly impoverished by the volutes being considerably reduced in size, and thereby losing to a great extent its importance as the chief characteristic of the capital. This fault, however, was afterwards greatly increased by the Italians. In the Greek examples the volutes were connected together by a series of mouldings or hem, hanging down over the echinus, after the manner of a festoon; but in the Roman there is merely a straight line without any moulding carried over the echinus, which is not nearly so graceful as in the former examples. In late specimens, the volute consists of fewer revolutions, and has no secondary spirals upon it; the mouldings of the spiral also, as well as the intermediate spaces between the spirals, are flat, and altogether the volute is less prominent, and less elaborately worked than in Grecian specimens. In the temple of Concord, the volutes are placed diagonally, similar to those of the capital termed Scamozzian, so as to present four similar faces. This is one amongst many varieties of the Roman-Ionic capital, of which there is no lack, some being ornamented with human figures, masks, busts, &c., as in an example given by Pyranesi. These differences are sufficient to show that the ancients did not confine themselves to one and the same treatment of this order on all occasions. The Italians in later times made very considerable alterations, first by reducing the size of the volutes, so as to make them insignificant, and afterwards, by attempting to remedy this defect, and give importance to the capital by the addition of an ornamental necking: another alteration consisted of the addition of festoons to the angular or Scamozzian capital, a festoon being suspended on each side of the capital, from the eye of one volute to that of the other on the same face; an example of this practice is to be seen in the portico to All-Souls Church, Langham-place, London. The Romans make use of the Attic base.

The Roman entablature differs also in some respects from the Grecian, and especially in the proportions of the cornice, which in the latter case is less than either of the other members, averaging at about $\frac{35}{100}$ of the entire entablature, whereas in examples of Roman practice, the cornice is by far the most important division of any, the proportions of the theatre of Marcellus giving 43 minutes to the architrave, 36 to the frieze, and 66 to the cornice, while those of the temple of Fortuna Virilis stand thus: architrave 38 minutes; frieze 29; cornice 70; which gives a great preponderance to the cornice. The projection of the cornice usually equals its height, or nearly so. The upper facia of the architrave is surmounted with a fillet and ogee often enriched, and the lower not unfrequently with a small echinus, also enriched, with a narrow fillet underneath. The frieze is mostly plain, and of little importance, but that of the temple of Fortuna Virilis has an attempt at decoration. The cornice is supported by an ogee-moulding, and dentil-band surmounted by a fillet, a bead-moulding, and a large enriched echinus; the cornice itself consisting of a corona with a small ogee and fillet, on which is placed a cymatium. In the dentil-band, the dentils are often of large size, and placed rather wide apart. The Italians have not unfrequently introduced into this order what is termed a pulvinated frieze, so called from its supposed resemblance to a cushion, its profile being convex; one of the earliest examples of the pulvinated frieze occurs in the baths of Diocletian.

The general proportions of the order, as adopted by the Grecian and Roman architects, are much alike; the principal differences existing, as we have shown, in matters of detail. Chambers gives the height of the column eighteen modules, and that of the entablature four and a half, or one-quarter the height of the column. The base is attic, and the shaft either plain or fluted, and in the latter case with twenty, or more frequently twenty-four, flutings with fillets between, which should not be broader than one-third of the width of the flutes, nor narrower than one-quarter. The ornaments of the echinus of the capital should correspond with the flutes, so as to have an egg or dart over the centre of each flute.

Modern examples of this order in London, are—

St. Pancras Church, copied from the Erectheion, and affording also a specimen of Caryatides with entablature, after the small building called the Pandrosium.

The East India House, after the Asiatic examples.

The portico of Hanover Chapel, Regent-street, after the order of Minerva Polias at Priene, which exhibits the peculiar Ionic base.

The New Post-Office.

The British Museum.

The portico of the College of Surgeons, after the small temple on the Ilissus.

The Church in Regent-square, New Road.

The Law Institution, Chancery-lane.

The subjoined table of proportions, as exhibited in various examples, may be found useful; it is extracted from Knight's Cyclopædia:—

	Height of Column.		Base of Shaft.		Upper diameter of Shaft.		Height of Entablature.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Temple of Apollo Epicurius, at Bassæ			2	1.9	1	9.4	3	9.31
Temple of Erechtheus, Athens	21	7.50	2	3.8	1	11.2	4	11.25
Aqueduct of Adrian	19	1.95	2	2.35	1	11.1	4	2.90
Temple on the Ilissus	14	8.300	1	9.4	1	6.2	3	7.282
Temple of Fortuna Virilis, at Rome	27	0	3	2	2	8.	6	8.6
							Architrave.	
Temple of Bacchus, at Teos.			3	3.6	3	1.8	2	5.4
Minerva Polias, at Priene			4	2.8	3	6.4		
Apollo Didymæus, near Miletus			6	3.2	5	5.8	3	5.2
Propylæa, at Eleusis			3	4.6	2	9.24		

The examples which we have selected for illustration, are as follows:—

Plate I.—Finished drawing of the order from the temple of Minerva Polias at Athens.

Plate II.—The same in outline.

Plate III.—Drawing in outline of column and entablature from the temple of Fortuna Virilis at Rome.

Plate IV.—Drawing in outline of column and entablature from the temple of Marcellus at Rome.

IRON, (from the Saxon *iren*,) a metal of a bluish-white colour; of great hardness and elasticity; very malleable; and exceedingly tenacious and ductile. The hardness of iron in some states is superior to that of any other metal; and it has the additional advantage of suffering this hardness to be increased or diminished at pleasure, by certain chemical processes, without altering its form. It is, nevertheless, easily formed into any shape, and susceptible of a high degree of polish; it is the most elastic of all the metals, and, next to platina, the most difficult of fusion. Its tenacity is also greater than that of any other metal, except gold—an iron wire, the tenth part of an inch in diameter, having been found capable of sustaining more than 500lbs. weight without breaking. Its ductility is such as to allow it to be drawn into wire as fine as a hair. It is the most abundant, the most important, and the most valuable of all the metals. Although a simple undecompounded substance, it is not naturally found in this state, except in comparatively minute quantities, but is the product of art. Some specimens of native iron, nearly pure, have been found in Siberia and South America; also many iron stones, rich in the metal, supposed to be of volcanic or meteoric origin, have been found in numerous parts of the earth; but all the iron of commerce is obtained by chemical means. Iron is so universally diffused as to form a constituent part of almost all animal, vegetable, and mineral substances. Unlike metals of inferior utility, its ores are not distributed in thin veins, or scattered in minute particles, but are thickly stratified over many thousands of square miles, chiefly in the northern regions of the earth, where nature has been less profuse of her other benefits. The use of this metal is of very great antiquity, though, on account of the difficulty of separating it from its ores, and of working it, probably not so remote as the employment of gold, silver, copper, and other comparatively soft metals, which are in many places found in a pure metallic state. It is stated by some writers, that iron is mentioned by Moses as the material of which knives and swords were fabricated; and that Herodotus mentions the presentation of a saucer or vase of iron, very curiously inlaid, by Alyattes, king of Lydia, to the Delphic oracle. Later and more erudite writers have, however, maintained, that the words of those ancient authors have been most incorrectly translated into our language; and that the working and use of iron was unknown at those periods. At what time the manufacture of iron was first attempted in Britain cannot be precisely ascertained. Some suppose (for it is in reality only a probable conjecture) that the Phœnicians, who wrought the tin-mines of Cornwall, introduced into the country men who were skilled in metallic ores, and capable of estimating their value, by applying the minerals to such purposes as their own necessities or the wants of the inhabitants might require. There is, however, much evidence to favour the belief that iron was worked in this country during the time it was in occupation by the Romans; and, that during the establishment of the Danes in England, the arts of mining and manufacturing the ores of iron were much improved.

Iron is obtained from the ore by an operation called smelting, and in this state it is called *crude-iron*, *cast-iron*, or *pig-iron*, but it is very impure. The art of smelting iron was practised in this country during the time of the Roman occupation; and in many ancient beds of cinders—the refuse of iron-works—Roman coins have been found. The principal ancient seats of the iron manufacture in this country appear to have been the Sussex and the Forest of Dean, or Arden, as it was then called. It is known that iron-works existed in that part of Gloucestershire in 1238, because there occurs, among the patent-rolls of Henry III. of that date, one entitled "De Forgeis levandis in Foresta de Dean." Remains of ancient iron-furnaces have been noticed in Lancashire, Staffordshire, and Yorkshire. The art of working in iron and steel was much practised in this island before the Norman conquest; and we are told, that not only was the army of Harold well supplied with weapons of steel and with defensive armour, but that the horses were covered with steel and iron armour; and that every officer of rank maintained a smith, who constantly attended his master to the wars, and took charge of his arms and armour, to keep them in proper repair.

The iron of commerce is usually divided into two distinct qualities, viz., pig-iron, and malleable or bar-iron—the second being the result of an extension of the processes necessary for the production of the first.

The first process is that of reducing the iron stone or ore into a metallic state by means of fusion. This operation is conducted in a blast-furnace, which is charged with certain proportions of iron-ore, of coke, and of limestone. The ore must previously have been roasted or calcined in a kiln, in order to drive out the water, sulphur, and arsenic, with which it is more or less combined in its native state; by the process, it loses one-sixth part of its weight. A furnace of the size commonly used in Wales will produce from 5 to 6 tons of pig-iron in twelve hours. For the largest quantity, the furnace must be charged progressively with 15 tons of roasted iron-ore, 22½ tons of coke, and about 6 tons of limestone. These ingredients are supplied at 50 charges, and must be intimately mixed together in the furnace. The limestone must be broken into small pieces; its use is to act as a flux to the ore, and promote its fusion. The heat that

would be produced in any furnace by merely setting fire to the fuel which is contained in it, would be altogether insufficient for the fusion of the ore, if its intenseness were not promoted by the forcing in of a current or blast of air. For this purpose it is necessary to use a strong mechanical force, and, of late years, the agency of steam has been commonly employed for this purpose. This power is applied to the working of a blowing cylinder, which may be four times the area of the cylinder of the steam-engine. If the blast thus produced were passed immediately from the blowing cylinder through the *tuyères* or tubes to the furnace, the effect would be intermitting and irregular, ceasing at the end of each stroke of the steam-piston. To remedy this inconvenience, the blast is carried into an intermediate chamber, of a spherical or cylindrical shape, called a regulator; and as the air is in a state of condensation when admitted, its effort to expand itself again to its natural volume causes the continuous and regular supply to the furnace which is necessary. The air thus forced into the furnace keeps the heat at the degree of intenseness which is indispensable for the smelting of the ore. Until the last few years, the air thus supplied was uniformly at the temperature of the atmosphere from which it was immediately taken; and the effect was, not only to produce a lower degree of heat, but also to supply a quantity of moisture which is prejudicial to the smelting process.

The blowing of heated air has, however, recently been introduced at several founderies, and likewise at the Clyde iron-works. This improvement is the invention of Mr. J. B. Nielson, of Glasgow, whose patent was enrolled in March, 1829, and is designated "an improved application of air to produce heat in fires, forges, and furnaces, where bellows or other blowing apparatus is required." He proposes, that the air supplied by any kind of machine shall, before it enters the furnace or cupola, be made to pass through an air-vessel heated to very high temperature—a red heat, if possible—by which means a current of hot air will be thrown on the fire, instead of the cold current usually employed. It is recommended that the air-vessel be surrounded with some non-conducting substance, and imbedded in masonry. The capacity of this vessel for a smith's forge he recommends to be about 1,200 cubic inches; and for a cupola or blast-furnace, about 10,000 cubic inches. It was much doubted whether the increased temperature of the fire thus blown would produce advantages equivalent to the expense of constructing the air-vessel and keeping it at the requisite heat; and, as respects the smelting of iron in particular, the theory seems opposed to the well-known fact, that a much larger quantity of iron is yielded by the blast-furnaces in the winter season, or when the air is cold, than during the summer season, when the air is warm. The experiment at the Clyde iron-works have, however, been reported most favourably of; and the saving of coal attending it is so great, that it was stated in the *Glasgow Chronicle* to be calculated to accomplish a saving in the consumption of this island to the amount of £200,000 annually. At the Clyde iron-works, the air was heated to 220° Fahrenheit before it was discharged into the furnace—an effect which was produced by the expenditure of only one-eleventh part of the cost of fuel it takes to heat it to the same temperature in the blast-furnace, which may be accounted for by the circumstance, that Mr. Nielson's air-vessel is heated by coals, while the blast-furnace is heated by coke. Further experience in this invention has fully confirmed the views of the patentee, and it must now be regarded as one of the most valuable improvements in modern metallurgic operations.

"The cost of the process of reduction by the hot-blast," observes Mr. Weale, in his 'Dictionary of Terms of Art,' "being so much less than that with the cold-blast, the ultimate value of the former is of course also partly dependent upon the quality of the produce. On this head much difference of opinion has often been manifested, and with all the earnestness usually displayed in the advocacy of self-interest. The value of each process must, no doubt, arise from the completeness of the fusion produced, and the separation effected between the iron, and the impurities combined with it in the ore. The hot-blast furnace effects the fusion more readily than the cold-blast, but admits a larger combination of cinders with the ore; and the advantage which has been taken of this facility of adulteration, in order to reduce the cost of production, has doubtless led to the introduction into the market of many qualities of hot-blast iron, which are inferior in strength to that made with the cold-blast. The results of some of the most carefully-conducted experiments which have been made upon the strength of cast-iron, and published in the sixth volume of the new series of "Memoirs of the Literary and Philosophical Society of Manchester," show that the transverse strength of the cold-blast iron tried was about 2½ per cent. greater than that of the hot-blast. The experiments here referred to were made upon rectangular bars 1 inch square, and 4 feet 6 inches long between the supports. The mean average breaking-weights, placed at the middle of these bars, were—

In 21 samples of hot-blast iron . . . 445.5714 lbs.
In 22 samples of cold-blast iron . . 456.9090 "

Cast iron, which is scarcely malleable at any temperature, is generally so hard as to resist the file, and is extremely brittle; however, it is equally permanent, in many applications, with wrought-iron, is less liable to rust, and being easily cast into various forms by melting, is much cheaper. Indeed, the labour of wrought-iron, if applied to many of the purposes to which cast-iron is used, would be incredible, and in some cases insurmountable.

The uses to which cast-iron is now applied, are so numerous, that it is quite impossible to particularize them. It is used extensively in the wheel-work of every department of machinery, in crane-work, in iron bridges, in beams, and pillars, for large buildings, and in numerous articles of manufacture. It is employed in the construction of works of the greatest magnitude, and of the most minute character. The immense iron-girders of a railway bridge are made of cast-iron, and offering a striking contrast to the delicate ornaments of the drawing-room fabricated of the same useful metal. Of late years, the perfection to which the art of moulding in iron has been brought is almost incredible, in particular, we may mention, beautiful specimens of ornamental railings, chimney-pieces, figures imitative of ancient sculptures, &c.

Cast-iron is reduced into wrought or bar-iron, or forged-iron, by divesting it of several foreign mixtures with which it is incorporated. The varieties of wrought-iron are the following: *hot-short iron* is so brittle when heated, that it will not bear the weight of a small hammer without breaking to atoms, but is malleable when cold, and very fusible in a high temperature; *cold-short iron* possesses the opposite qualities, and is with difficulty fusible in a strong heat, and though capable while hot of being beaten into any shape, is when cold very brittle, and but slightly tenacious. The iron in general use, which though, in a chemical point of view, not entirely pure, is so far perfect, that it possesses none of these defects; its principal properties are the following: 1st, When applied to the tongue, it has a styptic taste, and emits a peculiar smell when rubbed: 2nd, Its specific gravity varies from 7.6 to 7.8; a cubic foot of it weighs about 580lb. avoirdupois: 3rd, It is attracted by the magnet or loadstone, and is itself, in one of its ores, the substance which constitutes the

loadstone. It is also capable of acquiring itself the attraction and polarity of the magnet in various ways; iron, however, that is perfectly pure, retains the magnetic virtue only a very short time; 4th, It is malleable in every temperature, which, as it rises, increases the malleability. It cannot, however, be hammered out so thin as gold or silver, nor even as copper. Its ductility is very great, and its tenacity such, that an iron wire something less than the twelfth of an inch in diameter is capable of supporting, without breaking, 549¼lb. avoirdupois: 5th, It melts at about 158° of Wedgewood: 6th, It combines very readily with oxygen; when exposed to the air, its surface is soon tarnished, and is gradually changed into a brown or yellow colour, usually called *rust:* this change takes place more rapidly, in proportion as it is more exposed to moisture.

"Between the cast-irons made in different parts of Great Britain, there are characteristic differences. The Staffordshire metal runs remarkably fluid, and makes fine sharp castings. The Welsh is strong, less fluent, but produces bar-iron of superior quality. The Derbyshire iron also forms excellent castings, and may be worked with care into very good bar-iron. The Scotch iron is very valuable for casting into hollow wares, as it affords a beautiful smooth skin from the moulds, so remarkable in the castings of the Carron company, in Sterlingshire, and of the Phœnix foundery at Glasgow. The Shropshire iron resembles the Staffordshire in its good qualities."—*Dr. Ure, Dict. of Arts.*

The following statement shows the results of some interesting experiments on the cohesive strength of bar-iron, as detailed in an American publication:—

"The mean result of numerous experiments on wrought-iron, detailed in the *Journal of the Franklin Institute*, made by a Committee of the Institute, at the request of the Treasury Department of the United States.

	Specific gravity.	No. of experiments.	Strength in lbs.*
Missouri Bar Iron	7.7708	22	47,909
Missouri Slit Rods		2	50,000
Tennessee Bar	7.8046	21	52,099
Salisbury, Connecticut		46	58,009
Swedish Bar	7.4785	2	58,184
Centre County, Pennsylvania		15	58,400
Lancaster County, Pennsylvania	7.7400	2	58,661
English Ev. best patent Cable Bolt Iron	7.6897	5	59,105
English Ev. best patent Cable Bolt Iron, hammer hardened	7.6897(?)	8	71,000
Russian Bar	7.8014	5	76,069
Phillipsburgh Wire, diameter.. 333		13	84,186
190		5	73,888
156	mmmdmmm	5	89,162
Cast Steel		1	130,681

* Breaking-weight of an inch-square bar, deducting friction.

"The experiments were made at ordinary temperatures on bars of iron averaging ¾ inch by ¼ inch."

To preserve iron from rust, particularly when polished, various methods have been tried with more or less success: among others, the partial oxidation, known by the term *blueing*, has been adopted: the slightest coat of grease is sufficient to prevent rust.

With reference to this subject, more especially as to the effect of sea-water on cast-iron, Mr. Faraday addressed the following observations to Sir Byam Martin, chairman of the "Harbours of Refuge and Defence" commission:—

"Sir,—I hasten to reply to your note, though not, I fear, with any certain knowledge; for infirm health has prevented me from taking up the consideration of the action of sea-water on iron, as my observations will permit. I conclude that the question is of cast-iron in sea-water. Between these two bodies, there is a vigorous action. As far as I have been able to observe, it is the greatest in the water near the surface; less in deep water; and least of all when the iron is buried in sand, or earth, or building-materials (into which the water may penetrate;) for then the oxide and other results formed, are detained more or less, and form sometimes a cement to the surrounding matter, and always a partial protection. Soft cast-iron, as far as my experience goes (which is not much,) corrodes more rapidly than hard cast; soft cast-iron, as far as my experience goes, more rapidly than the brittle white iron. As to the amount of corrosion in any given time, I have not had the opportunity of observing any good and satisfactory cases of illustration.

"In estuaries and the mouths of rivers, it is very probable that great differences of corrosion will arise from the different circumstances of ariable saltness; the soil of the river, if near a town, the metallic will much affect it, thus a wharf of cast-iron might occasionally be greatly injured by making fast to it vessels that are coppered, using iron cables.

"As to the protection of iron, and first by a coating; the permanency of a coat of paint, or of tar, or bituminous matter, can only be ascertained by reference to experience. Of this I have none, except in a case where coated iron sheathed for vessels was brought to me. I was much impressed with the thorough adhesion of the coat to the iron. The process was patent, and I cannot remember whose it was. Zinc-ed iron would no doubt resist the action of the sea-water as long as the surface was covered with zinc, or even when partially crusted with that metal; but zinc dissolves rapidly in sea-water, and after it is gone, the iron would follow.

"As to voltaic protection, it has often struck me that the cast-iron piles proposed for light-houses, or beacons, might be protected by zinc, in the manner Davy proposed to protect copper by iron; but there is no doubt the corrosion of the zinc would be very rapid. If found not too expensive, the object would be to apply the zinc protectors in a place where they could be examined often, and replace them when rendered ineffective. In this manner, I have little doubt that iron could be protected in our sea-water. It is even probable that, by investigation and trial, different sorts of iron might easily be distinguished and prepared, one of which would protect the other; thus soft cast-iron would, probably, protect hard cast-iron, and then it would be easy to place the protecting masses where they could be removed when required.

"Hence, though iron be a body very subject to the action of sea-water, it does not seem unlikely that it might be used with advantage in marine constructions intended to be permanent, especially if the joint effects of preserving coats of voltaic protectors were applied. Perhaps engineers are in the possession of practical and experimental data sufficient to allow the formations of a safe judgment on this point. For my own part, I am not, and therefore am constrained to express the above opinions with much doubt and reserve."

Iron is the most useful and most plentiful of all metals. It requires a very intense heat to fuse it, on which account it can only be brought into the shape of tools and utensils by hammering: this high degree of infusibility would prevent the uniting of several masses into one, were it not from its being capable of welding, a property found in no other metal, except platina. In a white heat, iron appears as if covered with a kind of varnish; and in this state, if two pieces be applied together, they will adhere, and may be perfectly united by forging.

A very extensive manufacture of iron articles is now carried on at Birmingham, Sheffield, and other places, which, although they are cast from fluid metal, are nevertheless malleable. This property is derived from two causes; first, the pigs are prepared from the rich and pure iron ores of Cumberland; and the metal thus obtained, is combined with but a small quantity of carbon, so as nearly to resemble steel in colour, hardness, and the brilliancy of its fracture; and it has in consequence been designated by some manufacturers *run steel*. An infinite variety of articles, including nails, saddler's ironmongery, (and particularly such goods as afterwards receive another metallic coat, as those which are plated upon *steel*,) are cast from this metal. The castings thus produced are exceedingly brittle; but this property is entirely destroyed by a process termed annealing, in which the metal is deprived of the carbon to which its previous fusibility was owing, and is in consequence brought to that state of wrought iron requiring only the operations of the shingling forge and rollers to give it a laminated and fibrous texture. Nails made by this process may be drawn out longer, and bent backwards and forwards, without breaking. The metal is, however, not so strong or tough as hammered and rolled iron; the discovery of the process is nevertheless of great value, as many excellent articles are produced in consequence, which would not without it be made at double the cost. The discoverer of this mode of converting cast-iron goods into malleable, was Mr. Samuel Lucas of Sheffield.

A description of iron was introduced a short time since, under the name of corrugated iron, which has already met with great success, and promises to be very extensively used. It is called corrugated from its grooved or *wrinkly* appearance, produced by putting the sheets between rollers having grooved peripheries. Sheet-iron thus prepared, acquires a strength and stiffness much beyond its ordinary strength, and adapts it for purposes for which the common sheet-iron is found insufficient. Corrugated iron has been much used for roofs of railway stations, and works of a similar kind.

Formerly, large quantities of iron were imported from Russia and Sweden, and previously to the discovery in 1785 by Mr. Cort, of the methods of puddling and rolling or shingling iron, this country imported 70,000 tons of this metal, a vast quantity, considering the state of our manufactures at that time. So much, however, has our own wrought iron been improved in the manufacture, that it may now be considered fully equal to the Swedish. As a proof of this, the Admiralty, East India Company, and other public departments, now contract for British iron only. *See* STEEL.

Mr. Jessop, of the Butterley Works, estimated the annual produce in Great Britain (exclusive of Ireland) in 1840, at 1,396,400 tons; and the quantity of coal used for smelting that quantity was 4,877,000 tons, besides 2,000,000 tons for converting into wrought iron.

At the late meeting of the British Association at Cambridge, Mr. Watt read a report on the iron trade in Scotland, from which it appears, that, at the present moment, there are extensive new iron works erecting in Scotland, especially in Ayrshire and in Renfrewshire. At several of the old works, considerable additions are being made to the number of furnaces now at work. The increase in the annual quantity of pig-iron smelted in that country in April, 1845, amounts to 37.4 per cent.; and there is every appearance that, before another year expires, a similar increase will be made in the amount of iron produced in Scotland. Sir J. Guest, of Dowlars Works, in evidence before the Import Duties Committee, 1840, stated, that the iron made at the beginning of this century amounted to 150,000 tons.—In 1806, 258,000.—In 1823, 452,000.—In 1825, 581,000.—In 1828, 703,000.—In 1835, 1,000,000.—In 1836, 1,000,000.—In 1840, 1,500,000. We may remark, that the manufacture of malleable iron is yet but in its infancy in Scotland, although making rapid strides towards an important position. There are five establishments; and the present make may be computed at about 900 tons per week, or 50,000 tons per annum. For superior finish, toughness, and uniformity, it will stand comparison with either English or Welsh iron.

IRON BRIDGE, a species of bridge constructed, as its name implies, of iron, which was first applied to this purpose in England, towards the close of the 18th century. The merit of having employed this material in bridge-building, has been generally claimed for the English, but more accurate writers state that it really belongs to the Chinese. Be this as it may, it is certain that in no country in the world have been erected so many magnificent and stupendous structures as the iron bridges in the United Kingdom.

Under the article BRIDGE, (p. 58, vol. i.) we gave some account of the "rise, progress, and present state" of bridge-building, reserving to each respective head the more detailed information peculiarly belonging to it. Following that course, we now proceed to describe the several forms of bridges built of iron, as cast-iron arched bridges, cast-iron girder bridges, cast-iron compound girder bridges trussed with malleable iron bars, tubular bridges of various kinds, &c.

The first iron bridge erected in this country was over the Severn, a little below Colebrook Dale, where that river is narrow and rapid. The abutments, which are of stone, are brought to about 10 feet above the surface of common low-water, where they have each a platform of squared freestone for ten feet breadth, which serves for a hauling way, and a base for the arch to spring from. Upon this platform, cast-iron plates, four inches in thickness, are laid, and formed with sockets to receive the ribs. These plates, in order to save metal, have considerable openings in them. The principal, or inner ribs, which are five in number, and which form the arch, are 9 inches by $6\frac{1}{4}$. The second row behind them, and which are cut off at the top by the horizontal bearing-pieces, are $6\frac{1}{2}$ by 6 inches: the third row are 6 by 6 inches: the upright standards behind the ribs are 15 inches by $6\frac{1}{2}$ inches, but they have an open space in the breadth of $5\frac{3}{4}$; the back standards are 9 inches by $6\frac{1}{2}$, with projections for the braces; the diagonals, and horizontal ties, are 6 inches by 4, and the cast-iron tie bolts are $2\frac{1}{4}$ inches diameter. The covering plates, which are 26 feet in length, reaching quite across the bridge, are one inch in thickness. The great ribs are each cast in two pieces, meeting at the keys, which, as the arch is circular, 100 feet 6 inches span, and 45 feet rise, are about 70 feet in length. There are circular rings of cast iron introduced into the spandrels, and there is a cast-iron railing along each side of the roadway of the bridge: the weight of the whole of the iron work is $378\frac{1}{2}$ tons. Behind the iron work, at each extremity of the arch, the abutments are carried up perpendicularly of rubble masonry, faced with squared stone, and the wing-walls are also of the same materials.

The iron work was cast and put together in a very masterly manner, under the direction of Abraham Derby, of Colebrook Dale; and the whole was completed in the year 1779. The design was original and very bold, and was, as far as concerned the iron work, well executed; but being a first attempt, and placed in a situation where more skill than that of the mere iron-master was required, several defects became apparent when the bridge was completed. The banks of the Severn are here remarkably high and steep, and consist of coal measures, over the points of which vast masses of alluvial earth slide down, being impelled by springs

in the upper parts of the banks, and by the rapid stream of the river, which dissolves and washes away the skirts below: the masonry of the abutments and wing-walls not being constructed to withstand this operation, was torn asunder, and forced out of the perpendicular, more particularly on the western side, where the abutment was forced forward about 3 or 4 inches, and by contracting the span, of course heaved up the iron work of the arch. This was remedied under the direction of that able mason Mr. John Simpson, of Shrewsbury, as far as the nature of the case would admit of, by removing the ground, and placing piers and counter-arches upon the natural ground behind it. Had the abutments been at first sunk down into the natural undisturbed measures, and constructed of dimensions and form capable of resisting the ground behind; and had the iron work, instead of being formed in ribs nearly semicircular, been made flat segments, pressing against the upper parts of the abutments; the whole edifice would have been much more perfect, and a great proportion of the weight of metal saved. We have already stated that one row of the principal ribs formed the arch; the two rows behind are carried concentric with the inner row, until intersected by the roadway, which passes immediately at the level of the top of the inner ribs. This has a mutilated appearance; the circular rings of the spandrels being less perfect than if the pressure had been upon straight lines; for a circle is not well calculated for resistance, unless subjected to an equal pressure all round.

The second iron bridge was built upon the same river, about three miles above the former one, at a place called Buildwas. An old stone bridge was carried away by a very high flood early in 1795, and the county of Salop was obliged to restore the communication. Mr. Telford, the celebrated engineer, was at that time surveyor for the public works of the county, and on his recommendation, the magistrates ordered the construction of a cast-iron bridge, to be of one arch 130 feet span. The Colebrook Dale Company became contractors, both for the iron work of the arch, and the masonry of the abutments. Mr. Telford had some difficulty in making that company depart from their former mode of construction: but he at last prevailed in keeping the roadway low, and adopting the suspending principle, by means of a rib on each side of the bridge, which sprung from a lower base than the bearing ribs, and rose above them to the top of the railing; thus the bearing ribs were supported by the lower parts of those before mentioned, and were suspended by their upper parts. The bearing ribs have a curve of 17 in 130, or nearly one-eighth of their span. The suspending ribs rise 34 feet, or about one-fourth of their span. There are cast-iron braces, and also horizontal ties. There are 46 covering plates, each 18 feet in length, and one inch in thickness. They have flaunches 4 inches in depth, and are screwed together at each joint; so that, by taking the curvature of the bearing ribs, and being firmly secured at the abutments, instead of a load, they compose a strong arch. There being only one rib in the middle of 18 feet breadth of bridge, on each covering plate, a cross rib or flaunch, 4 inches in depth, is cast at an equal distance between the bearing ribs. The suspending ribs are each 18 inches in depth, and $2\frac{5}{8}$ inches in thickness, exclusive of a moulding. The bearing ribs are 15 inches in depth, and $2\frac{1}{2}$ inches in thickness, and each of the ribs is cast in three pieces only, of about 50 feet each; the braces are 5 by 3 inches. The principal king-posts are $10\frac{1}{4}$ by $4\frac{1}{2}$ inches. The springing plates are each 3 feet broad, and 3 inches thick, with openings to save metal. The uprights against the abutments are $4\frac{1}{2}$ inches square. The strongest uprights in the railing are 3 inches square, and those between them 1 inch. They are placed 6 inches apart, between middle and middle. The height of the railing above the surface of the roadway, is 4 feet 9 inches. In each spandrel, there are three circular arches formed with hard-burned bricks, which preserve most of the space open, but they are concealed by iron plates, one inch in thickness, which form the outside facings. On the eastern side of the river, although the banks are not so very high or steep, the quality of the ground being similar to that of the other iron bridge, particular care was bestowed upon the abutments: the space for them was excavated down to the rock, which lay considerably under the bed of the river, and the masonry was sunk into the solid part of the rock. It was built up chiefly of square masonry, and the rest of rubble, laid very close in regular courses, and having the back part formed in the shape of a wedge, pointing to the bank. The wing-walls were curved horizontally and vertically. At the height of 10 feet above the low-water, there is a hauling path on each side of the river. This bridge, which was completed in 1796, has never shown any appearance of failure in any of its parts; nothing can be more perfect than the iron work; it is fitted as correctly as a piece of good carpentry.

It has been objected to this structure, that by connecting ribs of different lengths and curvature, they are exposed to different degrees of expansion and contraction. This appears just in theory; and that no discernible effect has hitherto been produced, is probably from the difference being small. Another objection is, an apparent heaviness in the spandrels, from concealing the circular arches with iron plates. For appearance, these spaces had certainly better not have been concealed, but they are not liable to the objections made to the former iron bridge, because the space around them is all closely filled up; and the roadway being formed with materials similar to this filling-up matter, distributes the pressure very regularly. Upon the whole, considering the strength acquired by placing the covering plates with their deep flaunches, in the form of an arch, we doubt whether a greater degree of strength can be had by any other distribution of the same quantity of cast-iron, viz., $173\frac{1}{2}$ tons: it appears to us, however, that the upright standards, braces, and king-posts, might be made of smaller dimensions.

The third iron bridge was constructed over the river Wear, near Sunderland, in the county of Durham. Its projector was Rowland Burdon, Esq., a gentleman of considerable landed property in that county, and who, for some time, represented it in parliament. The iron-work was cast at the founderies of Messrs. Walkers, of Rotherham, and erected under the inspection of Mr. Thomas Wilson. The confidence in the use of iron for arches of great extent, was by this time established. The span of the second arch, we have seen, is 30 feet more than that of the first; and, in this third instance, the span is 106 feet beyond that of the second, although its rise is only the same as that of the suspending ribs at Buildwas. The arch at Sunderland springs 60 feet above the level of the surface of low-water; the span is 236 feet; the rise, or versed sine, is 34 feet; the width of the roadway 32 feet; and there are six ribs.

In this arch the mode of construction is very different from either of the former. Instead of working with pieces of iron from about 50 to 70 feet in length, each rib is here composed of 125 small frames, each about two feet in the length or curve of the rib, and 5 deep in the direction of the radius. In each frame there are three pieces of 4 inches square, which run in the direction of the curve of the arch; and these are connected in the direction of the radius by two other pieces, 4 by 3 inches. In each side of the larger pieces is a groove, 3 inches broad, by three-quarters of an inch in depth; and opposite each cross piece there is a hole

in the middle of the groove. When the abutments were brought up, and a scaffolding constructed across the river between them, six of these frames were placed against the abutments in the manner of arch-stones. Wrought-iron bars, of a length to embrace sundry frames, were then fitted into the grooves. Hollow pipes of cast-iron, 4 inches in diameter, fitted to reach between each two frames, across the soffit, were introduced. Upon the ends of these pipes are flaunches, in which there are holes, answerable to the holes in the four-inch pieces of the frames, and also to those of the wrought-iron bars. Through these holes wrought iron bolts were introduced, which brought all the before-mentioned parts together by means of fore-locks. The frames do not meet at the upright pieces, but on the three points of the four-inch pieces only. On the ends of the hollow pipes, there are small projecting pieces, which embrace the upper and lower edges of the frames opposite each joining. These operations were repeated until the whole of the frames were placed, and the arch keyed, forming six ribs between the abutments. Upon the ribs, perpendicular pillars are placed; and between them are cast-iron circles, which come in contact with the extrados, the upright pillars, and the bearers of the roadway. The bearers and covering, we suppose for cheapness, are made of timber: the railing is cast-iron. The inclinations each way upon the arch, probably to save weight, are inconveniently steep.

From its great elevation and lightness of construction this bridge is justly esteemed a bold effort of art, and a magnificent feature in the country. The wooden bridges in Switzerland, and that in America, are of greater span; but, being placed near the surface of the water, and from the difference of material, their parts being of larger dimensions, there can be no comparison as to the fineness of effect. A cast-iron bridge was also built over the river Witham, at Boston, in Lincolnshire, the design for which has been generally ascribed to Mr. Rennie. That gentleman, however, only gave the width and rise of the arch, and the abutments were founded and built under his direction. The iron arch itself was designed and executed by Mr. Thomas Wilson, of Sunderland. The span of this arch is about 85 feet; the rise about 5 feet 6 inches; the breadth is 36 feet; and there are eight ribs, each rib composed of eleven frames, 3 feet deep in the direction of the radius. At each joining there is a cast-iron grating across the arch which connects the frames, on the same principles as practised at the Pontcysylte aqueduct. Instead of three pieces in the direction of the curve, as at Sunderland, here are only two, but they are 7 inches by 4½. These are, in each frame, connected in the direction of the radius, by pieces, 4 by 3 inches. Upon the back of the ribs, pillars, 4 by three inches, are placed perpendicularly to support the roadway. The superstructure resembles that of the first iron bridge at Colebrook Dale. The arch has been kept very flat, to suit the tide below and the streets above. The frames being made about four times the length of those at Sunderland, and being connected with cast-iron gratings instead of wrought-iron, are essential improvements; but from the pieces in the frames, which are in the direction of the radius, being only 4 by 3 inches, while the main pieces in the direction of the curve are 7 by 4½, a great proportion of the former are broken. This is a defect; and the pillars which support the roadway being perpendicular, do not correspond with the radiated pieces of the frames. The ribs, in springing from the perpendicular face of the masonry of the abutment have also a crippled appearance.

In the improvements made under the direction of Mr. Jessop, at the port of Bristol, it became necessary to change the course of the river Avon, and two very handsome cast-iron bridges were built over the new channel. The span of the iron work of each arch, is 100 feet; the rise 12 feet 6 inches, or one-eighth of the span; the breadth is 30 feet. There are six ribs; each rib is composed of two pieces meeting in the middle, and they are connected crosswise by nine cast-iron ties, which are dovetailed, and wedged into the ribs; the cross sections of these ties are in the form of the letter T. The ribs stand upon abutment-plates, which are laid in the direction of the radius. These plates are 32 feet in length, 2 feet 4 inches in breadth, and 4 inches in thickness. In each plate are 5 apertures, each 5 feet long, and 20 inches in width. The ribs are 2 feet 4 inches in depth in the direction of the radius, and two inches in thickness, and have each 80 apertures, one foot square, separated by bars 3 inches broad, excepting opposite the cross ties, where the solid is 12 inches broad. Where the ribs meet in the middle they have flaunches, 8 inches broad and 2 thick, and they are connected by cast-iron screw-bolts, 3 inches in diameter. Between the ribs and the bearers of the roadway, perpendicular pillars, with cross sections formed like the letter T, are placed: the bearers are of the same form. The whole is covered with cast-iron plates, and there are railings of cast-iron.

There is great simplicity, and much of correct principle, in this design: 1. The springing-plates being placed in the direction of the radius, and the abutments receding to produce a space behind the ribs equal to that between the upright pillars. 2. The ribs being composed of two pieces, and one joint only: and, 3. Wrought-iron being wholly excluded. But we regret still observing the varying dimensions of the parts of the ribs; and that the supporting pillars are still placed perpendicularly; and which, as the arch has more curvature, has a yet worse effect than at Boston.

In the course of his employment as engineer to the board of parliamentary commissioners for making roads and constructing bridges in the Highlands of Scotland, Mr. Telford erected a cast-iron bridge over an arm of the sea, which divides the county of Sutherland from that of Ross, at a part where several of those roads unite. In this bridge, the defects noticed in the former works of this sort appear to be avoided. The arch is 150 feet span; it rises 20 feet, it is 16 feet in width, and has 4 ribs. In the abutments, not only are the springing-plates laid in the direction of the radius, but this line is continued up to the roadway. The springing-plates are each 16 feet in length, 3 feet in breadth, and 4 inches in thickness, with sockets and shoulder-pieces to receive the ribs. In each plate are 3 apertures, 3 feet in length and 18 inches in width. Each of the ribs, for the conveniency of distant sea-carriage, is composed of 5 pieces, 3 feet in depth in the direction of the radius, and 2½ inches in thickness. There are triangular apertures in the ribs, formed by pieces in the direction of the radius, and diagonals between them; but every part is of equal dimensions. At every joining of the pieces of the ribs, a cast-iron grating passes quite across the arch; upon these are joggles or shoulderings to receive the ends of the ribs: the ribs have also flaunches, which are fixed to the gratings with cast-iron screw-bolts. Each rib is preserved in a vertical plane, by covering the whole with grated, flaunched plates, properly secured together, and to the top of the ribs, by cast-iron screws and pins. In the spandrels, instead of circles or upright pillars, lozenge, or rather triangular forms, are introduced, each cast in one frame, with a joggle at its upper and lower extremities, which pass into the sockets formed on the top of the ribs, and in the bearers of the roadway. Where the lozenges meet in the middle of their height, each has a square notch to receive a cast-iron tie, which passes from each side,

and meets in the middle of the breadth of the arch, where they are secured by fore-locks. Next to the abutments, in order to suit the inclined face of the masonry, there are half-lozenges. By means of these lozenge or triangular forms, the points of pressure are preserved in the direction of the radius. The covering-plates, in order to preserve a sufficient degree of strength, and lessen the weight, are, instead of solid, made of a reticulated shape; the apertures widen below, to leave the matter between them a narrow edge; and contract upwards, so as to prevent the matter of the roadway from falling through. This disposition of the iron-work, especially in the spandrels, also greatly improves the general appearance.

The success which had attended the use of iron, as a material in bridge building, had now given such confidence to engineers, that works of the greatest magnitude were proposed by the master-minds of Telford, Rennie, and others. At this period, the practicability of constructing a bridge over the Menai Straits had been much discussed. It was deemed expedient by government to facilitate, as much as possible, the intercourse between England and Ireland. For this purpose, an investigation was made as to the most effectual mode of improving the mail-roads from Holyhead through North Wales.

The Island of Anglesea, as is well known, is separated from Carnarvonshire by the celebrated strait or arm of the sea, named the Menai, through which the tide flows with great velocity, and, from local circumstances, in a very peculiar manner. This rendered the navigation difficult, and it had always been a formidable obstacle in the before-mentioned communication. The passage between Anglesea and the opposite mainland was maintained by six ferries, the chief of which was called Bangor Ferry, from its proximity to that town; but a permanent connection, by means of a bridge, had been in contemplation, and various projects for one had been under consideration. From a report of the House of Commons, of June 1810, it appears, that Mr. Rennie, the engineer, had given plans and estimates for bridges at this place in 1802, and had been called on to revise them in 1810. His plans, which appear in the last-mentioned report, are, 1st, One arch of cast-iron, 450 feet span, over the narrowest part of the strait, at a projecting rock named Ynys-y-Moch: and, 2nd, Another upon the Swilley rocks, consisting of three cast-iron arches, each 350 feet span. The expense of that at Ynys-y-Moch is estimated at £259,140, and of that at the Swilley, £290,147. He prefers the latter, because he says, "On account of the great span of the arch at Ynys-y-Moch, and the difficulty and hazard there will be in constructing a centre to span the whole breadth of the channel at low-water, without any convenient means of supporting it in the middle, on account of the depth of water and rapidity of the tide, or of getting any assistance from vessels moored in the channel to put it up; I will not say it is impracticable, but I think it too hazardous to be recommended." And, again, in the same report: "I should be little inclined to undertake the building a bridge at Ynys-y-Moch."

But from the report of June, 1811, it appears that, in May 1810, Mr. Telford was instructed by the Lords of the Treasury to survey, and report upon the best method of improving the lines of communication between Holyhead and Shrewsbury, and also between Holyhead and Chester; and to consider, and give plans for passing the Menai. In the aforesaid report (of 1811), we have his plans and estimate. His explanations we shall give in his own words; but before doing so, it is necessary to observe that much of the following extract may, perhaps, more properly belong to the description of the Menai bridge, which will be found under the head Suspension Bridge. It is, however, given here, as it describes a mode of constructing centres applicable as well to stone as to iron arches:—

"The duty assigned me," says Mr. Telford, "being to consider, and report respecting a bridge across the Menai, I shall confine myself to this object. Admitting the importance of the communication to justify acting on a large scale, I not only consider the constructing a bridge practicable, but that two situations are remarkably favourable. It is scarcely necessary to observe, that one of these situations is at the Swilley rocks, and the other at Ynys-y-Moch. These two being so evidently the best, the only question that can arise is, to which of them the preference ought to be given.

"From the appendix to the second report to the Holyhead roads and harbour, it appears that a considerable number of small coasting vessels, viz., from 16 to 100 tons, navigate the Menai, and that there have been a few from 100 to 150 tons. By statements from the principal ship-builders in the river, made in the year 1800, to the committee for improving the port of London, it also appears that vessels of 150 tons, when they have all on end, are only 88 feet in height above the water-line; and farther, that even ships of 300 tons, with their top-gallant masts struck, are nearly the same height; these in the Menai are extreme cases, and, if provided for, ought, as to navigation, to satisfy every reasonable person; it may, indeed, rather be a question whether the height should not be limited to vessels under 100 tons, by which the expense of a bridge would be considerably diminished.

"In the plans I have formed, provision is made for admitting vessels of 150 tons to pass with all on end; that is, in one design preserving 90 feet, and in the other 100 feet, between the line of high-water and the lower side of the soffit of the arch. The first design is adapted for passing across the three rocks, named the Swilley, Benlass, and Ynys-well-dog, which, by their shape and position, are singularly suitable. To embrace the situation most perfectly, I have divided the space into three openings of 260 feet, and two of 100 feet each, making piers each 30 feet in thickness. Over the three large openings, the arches are made of cast-iron; over the smaller spaces, in order to add weight and stability to the piers, semicircular arches of stone are introduced; but over these, as well as the larger openings, the spandrels, roadway, and railing, are constructed of cast-iron. In this way the navigation is not impeded, because the piers, standing near the outer edges, are guards for preventing vessels striking upon the rocks; while the whole structure presents very little obstruction to the wind. From the extremity of the abutments, after building rubble walls above the level of the tideway, I propose carrying embankments until the roadway reaches the natural ground. The annexed drawing will sufficiently explain the nature of the design. I propose the bridge to be 32 feet in breadth; and, from minute calculations made from detailed drawings, I find the expense of executing the whole in a perfect manner amounts to £158,654.

"The other design is for the narrower strait, called Ynys-y-Moch. Here the situation is particularly favourable for constructing a bridge of one arch, and making that 500 feet span, leaves the navigation as free as at present. In this I have made the height 100 feet in the clear at high water spring tides; and I propose this bridge to be 40 feet in breadth. Estimating from drawings, as already described, I find the expense to be £127,331, or £31,323 less than the former. From leaving the whole channel unimpeded, it is certainly the most perfect scheme of passing the Menai; and would, in my opinion, be attended with the least inconvenience and risk in the execution.

"In order to render this evident, I have made a drawing,

to show in what manner the centering or frame, for an arch of this magnitude, may be constructed. Hitherto, the centering has been made by placing supports, and working from below; but in the case of the Menai, from the nature of the bottom of the channel, the depth at low-water, and the great rise and rapidity of the tides, this would be very difficult, if not impracticable. I therefore propose changing the mode, and working entirely from above, that is to say, instead of supporting, I mean to suspend the centering. By inspecting the drawing, the general principle of this will be readily conceived.

"I propose, in the first place, to build the masonry of the abutments as far as the lines A B, C D, and in the particular manner shown in the section. Having carried up the masonry to the level of the roadway, I propose upon the top of the abutments to construct as many frames as there are to be ribs in the centre; and of at least an equal breadth with the top of each rib. These frames to be about 50 feet high above the top of the masonry; and to be rendered perfectly firm and secure. That this can be done, is so evident, I avoid entering into details respecting the mode. These frames are for the purpose of receiving strong blocks or rollers and chains, and to be acted upon by windlasses or other powers.

"I next proceed to construct the centre itself; it is proposed to be made of deal baulk, and to consist of four separate ribs; each rib being a continuation of timber frames, 5 feet in width at the top and bottom, varying in depth from 25 feet near the abutments to 7 feet 6 inches at the middle or crown. Next to the face of the abutments, one set of frames, about 50 in length, can, by means of temporary scaffolding, and iron chain bars from the before-mentioned frames, be readily constructed, and fixed upon the offsets of the abutments, and to horizontal iron ties laid in the masonry for this purpose. A set of these frames (four in number) having been fixed against the face of each abutment; they are to be secured together by cross and diagonal braces, and there being only spaces of 6 feet 8 inches left between the ribs, (of which these frames are the commencement,) they are to be covered with planking, and the whole converted into a platform, 50 feet by 40. By the nature of the framing, and its being secured by horizontal and suspending bars, I presume every person accustomed to practical operations will admit that these platforms may be rendered perfectly firm and secure.

"The second portion of the centre frames, having been previously prepared and fitted in the carpenter's yard, are brought, in separate pieces, through passages purposely left in the masonry, to the before-mentioned platforms. They are here put together, and each frame raised by the suspending bars and other means, so that the end which is to be joined to the frame already fixed, shall rest upon a small movable carriage. It is then to be pushed forward, perhaps upon an iron railroad, until the strong iron forks, which are fixed on its edge, shall fall upon a round iron bar, which forms the outer edge of the first, or abutment frames. When this has been done, strong iron bolts are put through eyes in the forks, and the aforesaid second portion of the frame-work is suffered to descend to its intended position, by means of the suspending chain-bars, until it closes with the end of the previously fixed frame, like a rule joint. Admitting the first frames were firmly fixed, and that the hinge part of this joint is sufficiently strong, and the joint itself 20 feet deep, I conceive, that even without the aid of the suspending bars, this second portion of the centering would be supported; but we will for a moment suppose, that it is to be wholly suspended. It is known, by experiment, that a bar of good malleable iron, one inch square, will suspend 80,000 lb., and that the powers of suspension are as the sections: consequently, a bar $1\frac{1}{2}$ inch square, will suspend 180,000 lb.; but the whole weight of this portion of the rib, including the weight of the suspending bar, is only about 30,000 lb., or one-sixth of the weight that might safely be suspended; and as I propose two suspending chain-bars to each portion of rib, if they had the whole to support, they would only be exerting about one-twelfth of their power; and considering the proportion of the weight which rests upon the abutments, they are equal also to support all the iron work of the bridge, and be still far within their power.

"Having thus provided for the second portion of the centering a degree of security far beyond what can be required, similar operations are carried on from each abutment until the parts are joined in the middle, and form a complete centering; and being then braced together, and covered with planking where necessary, the whole becomes one general platform or wooden bridge, to receive the iron-work.

"It is, I presume, needless to observe, that upon such a centering or platform, the iron-work, which, it is understood, has been previously fitted, can be put together with the utmost correctness and facility: the communication from the shores to the centre will be through the before-mentioned passages in the masonry. The form of the iron-work of the main ribs will be seen, by the drawing, to compose a system of triangles, preserving the principal points of bearing in the direction of the radius. It is proposed in the breadth of the bridge (*i. e.* 40 feet) to have nine ribs, each cast in twenty-three pieces, and these connected by a cross-grated plate, nearly in the same manner as in the great aqueduct of Pontcysylte, over the valley of the Dee, near Llangollen. The fixation of the several ribs in a vertical plane, appearing (after the abutments) to be the most important object in iron bridges, I propose to accomplish this by covering the several parts or ribs, as they are progressively fixed, with grated, or reticulated and flaunched plates, across the top of the ribs. This would keep the tops of the ribs immovable, and convert the whole breadth of the bridge into one frame. Besides thus securing the top, I propose also having cross-braces near the bottom of the ribs.

"The ribs being thus fixed, covered, and connected together, the great feature of the bridge is completed. And as, from accurate experiments made and communicated to me by my friend, the late William Reynolds, of Colebrook Dale, it requires 448,000lb. to crush a cube of one quarter of an inch of cast-iron, of the quality named gun-metal, it is clear, while the ribs are kept in their true position, that the strength provided is more than ample.

"When advanced thus far, I propose, though not to remove, yet to ease the timber-centering, by having the feet of the centering ribs (which are supported by offsets in the masonry of the front of the abutment) placed upon proper wedges; the rest of the centering to be eased at the same time by means of the chain-bars. Thus the hitherto dangerous operation of striking the centering, will be rendered gradual and perfectly safe; inasmuch that this new mode of suspending centering, instead of supporting it from below, may perhaps hereafter be adopted as an improvement. Although the span of the arch is unusually great, yet by using iron as a material, the weight upon the centre, when compared with large stone arches, is very small. Taking the mere ring of arch-stones in the centre arch of Blackfriars' bridge, $156 \times 43 \times 5$, equal to 33,450 cubic feet of stone, it amounts to 2,236 tons; whereas the whole of the iron work, in the main ribs, cross-plates, and ties, and grated covering plates, that is to say, all that is lying on the centering at the time it is to be eased, weighs only 1,791 tons. It is true, that from the flatness of the iron arch, if left unguarded, a

great proportion of this weight would rest upon the centering; but this is counterbalanced by the operation of the iron ties in the abutments, and wholly commanded by the suspending chain-bars.

"When the main ribs have been completed, the next step is to proceed with the iron supporters of the roadway; and these, instead of being constructed in the form of circles, or that of perpendicular pillars, as hitherto, are here a series of triangles, thus including the true line of bearing. These triangles are, of course, preserved in a vertical plane by cross ties and braces. Iron bearers are supported by these triangles, and upon the bearers are laid the covering plates under the roadway, which, instead of being solid, are (in order to lessen the weight) proposed to be reticulated.

"If I have, throughout this very succinct description, made myself understood, it will, I think, be admitted, that the constructing a single arch across the Menai, is not only a very practicable, but a very simple operation; and that it is rendered so, chiefly by adopting the mode of working from each abutment, without at all interfering with the tideway.

"In the case of the Swilley bridge, although the arches are smaller, yet being placed on piers, situated on rocks, surrounded by a rapid tide, the inconvenience of carrying materials, and working, is greatly increased; and supposing the bridge part constructed, an enormous expense is still to be incurred before the roadway can be carried over the flat ground on the Anglesea shore. Therefore whether economy, facility of performance, magnificence, or durability, be consulted, the bridge of one arch is, in my opinion, infinitely preferable; and it is no less so, if considered in what regards the navigation." *See* SUSPENSION BRIDGE.

A very handsome bridge was erected over the river Trent, in the county of Stafford, from the designs and under the direction of James Potter, Esq. The specification for this structure is so ably drawn, and describes so precisely every part of the works to be contracted for, that we think we shall do good service to the student, by transcribing it *in extenso*, as a model for similar compositions.

SPECIFICATION OF WORKS.

Mason's Work.—"Specification of the mason's work of the abutments for the iron bridge intended to be erected over the river Trent, at a place commonly called High Bridge, near to Handsacre in the county of Stafford:—

"The footings to be in 3 courses, laid on level beds; the courses to be not less than 1 foot thick, and the front or outside courses to be laid header and stretcher alternately; the stretchers to be not more than 4 feet long, and to average 2 feet in width upon the beds; the headers to average 4 feet in length, and 2 feet upon the beds; the stones to be all properly worked on the beds, that is, to have a tool draught round them, and dressed off fair between with a point or pick: the joints or ends of the stretchers to be squared their whole length, and the joints of the headers squared in the width of the stretchers, and the other parts dressed or squared with a pick; all the space between the courses to be filled in with ashlar of the same thickness as the outside courses, the beds prepared as before directed, and thes ides and ends squared with a pick, and laid in proper bond to fall in with the outside courses, and when a course is finished, to be grouted; the whole surface is then to be dressed off level before another course is begun to be set.

"The front courses of these abutments, cutwaters, and wing-walls, to be not less than 1 foot thick; laid on level beds with bond, that is, the joints to overlap about 8 inches, header and stretcher alternately; the headers to average 3 feet 6 inches wide; the stretchers to be not more than 4 feet in length, and 1 foot 6 inches wide. The beds of the stones to be all worked fair, and the joints squared the width of the stretchers, and the face of them clean-tooled. The wing-walls to be built curvilinear on the plans, finishing with octangular piers, and battering in a curve line 3 feet in the whole height; the joints to be rusticated.

"The hearting of the abutments, that is, between the outside courses to be worked, to fall in with the radii of the arch, as shown on the section. The stone composing this part of the abutments, to be about 1 foot thick where they terminate at the bottom, and when they extend to require stones more than 18 inches thick, they may be in two courses if required; the stones must average not less than 2 feet upon the beds, and from 3 to 4 in length; the beds to be fair dressed by a tool draught round, and dressed off between with a pick; the headings and side joints squared and set in proper bond as before expressed; and when one course is set, it must be dressed off fair to its radii, and grouted before another course is begun.

"The springing-stones, that is, those on which the springing plates of the arch are to rest, to be 4 feet on the face on which the plates rest; the projection, or string-course, to be worked on the same stones. These stones to be not less than 3 feet on the beds.

"The cornice and plinth of the wing-walls, and piers, to be worked according to drawings, that is, to match the iron cornice. The caps of the piers and cutwaters to be each in one stone, and worked as shown on the drawings.

"To be a puddle of clay 3 feet thick put in against the back of the abutments, and wing-walls carried up with the masonry as it proceeds, and filled in behind with spoil (got out from the foundations) to the extent of the wing-walls, and well rammed down to keep the puddle in its proper place.

"The stone to be used for the works to be got from Tixall or Western quarry, or any other of as good a quality; it must be free from clay-holes or dry rents, and all to be set on its natural or quarry bed.

"The mortar to be composed of barrow lime and river or drift sand, two parts of sand to one of lime; mixed up in small quantities, as it is used, with as little water as possible, and well beat with a beater before it is used. The grout must be made with the same lime mixed up with coarse sand and small gravel, in the same proportion as above mentioned.

"The contractor must find all materials, tools and utensils, for his part of the work, and shall not let any part of the work, except quarrying the stone, and carriage of the same and other materials, to any person, but the whole to be done by men on day-wages. The excavating the earth for the foundations, to be done by the county.

"The works are to be done under the superintendence of the surveyors of the public works for the county of Stafford, or such surveyor as the justices assembled in quarter sessions shall at any time hereafter appoint; and should it at any time appear during the execution of any parts of the works to such surveyor, that the contractor is neglecting or doing any part of the work contrary to the true meaning and intent of this specification, the magistrates shall have it in their power to take the work out of his hands, and employ others to finish it; and what money may be due to the said contractor, to remain in the hands of the treasurer of the county till the whole is completed; and any loss that may be sustained by the neglect or misconduct of the said contractor, to be paid for out of it.

"*Iron work.*—Specification of the iron work for a bridge intended to be erected over the river Trent, at a place commonly called High Bridge, near to Handsacre, in the county of Stafford:—

"Upon each abutment is to be a springing plate of cast-iron, each cast in one piece, and to have shoulderings and sockets to receive the ends of the ribs. Each plate is to be of the form and dimensions as shown upon the drawings. The back of each socket, or the part against which the ends of the ribs will abut, is to be clipped, and made to have a true and even face to the exact radius of the arch.

"There is to be but one arch of 140 feet span, and rising 14 feet; the arch is to be composed of 5 ribs, each cast in 7 pieces of equal lengths. The ribs are to be 36 inches deep, in the direction of the radius, and of the exact shape and dimensions as shown upon the drawings. The parts of each rib and the ribs are to be connected by cast-iron tie or connecting plates, each cast in one piece, and passing quite across the arch; the parts composing each rib are to have flanges cast upon each of the ends which abut against the connecting or tie plates, and are to be secured to them by 3 inch square threaded wrought iron screw-pins in each flange. Each flange is to be clipped, and made true over the whole of its surface to the exact radius of the arch, so as to have a solid and true joint. The ends of the parts of the ribs which are to be fixed in the sockets of the springing-plates are to be clipped, and made true over their whole surface of section, so that they may have a sound, solid, and true abutting joint. The parts of each tie or connecting plate against which each part of the rib abuts, must, for the whole area of each flange, be made to the exact radius of the arch, and be clipped and made to have a true and even face. Joggles are also to be cast upon each tie or connecting plate, which are to fit into the joggles cast on the ends of the parts of the ribs. Both the male joggles upon the tie or connecting plates, and the female joggles at the ends of the ribs, are to be made to the radius of the arch, and clipped, and made true over their whole surface, so that each joint may be solid and true throughout.

"Upon the top of each of the ribs is to be a shouldering, running its whole length, having sockets to receive the joggles upon the bottom of the spandrils. Diagonal braces of cast-iron, of the same section, form, and dimension, and disposed in the manner as represented in the drawings, are to be used; each of the parts composing the braces are to abut against the ribs in the situations and in the manner shown upon the drawings, and secured to them by keys and cotters, or wedges, filed, and made true upon their edges; the parts of the braces which abut against the ribs, and also the face of the snugs or bed-pieces, cast upon the ribs to receive them, must be chipped so that they may have a true solid joint.

"The spandrils are to be of the same form and dimensions as shown upon the drawing. The spandrils over each rib are to be the same in every respect, excepting that upon the outside face of the outside spandrils a fillet must be cast, running round each opening, as shown upon the drawing; the fillet to be 1½ inch wide, and projecting ¾ of an inch upon the bottom of the spandrils; at the point of each lozenge must be cast joggles to fit into sockets on the tops of the ribs. Ears also to be cast at the same place; the situations of the joggles and ears marked upon the drawings. At the central intersection of each lozenge there must be a brace running quite across the bridge; each must be done as shown upon the drawings, viz., having a wrought-iron screw bolt 1½ inch in diameter, passing through cast-iron tubes, with washer, plates, &c., quite across the bridge. These braces are to be placed in the situations as marked upon the drawings. The spandrils may be cast in any convenient lengths, and connected by flanges of proper strength, and 1½ inch wrought-iron screw-pins.

"The outside spandrils are also to have a flange cast on their tops, running the whole length of the bridge, to bed the cornice, &c., upon.

"The cornice is to be of the same form and dimension as shown upon the drawing, having strengthening pieces cast inside, not farther asunder than 3 feet. It must be cast in lengths not exceeding 9 feet; and each piece is to be connected to the other by internal flanges and three 1¼ inch wrought-iron screw-pins in each joint. The bottom of the cornice will lie upon a flange cast upon the top of the outside spandrils, and be secured to it, and the road-plates 1½ inch wrought-iron screw-pins, two in each road-plate.

"The plinth is to be of the dimensions and form as shown upon the drawings; it must be cast in lengths not exceeding 8 feet 6 inches, each piece to be connected to the other by a dove-tailed joint. Ears are also to be cast on the bottom of each side, to secure it to the top of the cornice by 1¼ inch wrought-iron screw-pins, not more than two feet asunder. Sockets are to be cast in the top of the plinth, to receive.

"The palisade bars are to be 1¼ inch square, placed arris-ways, and not more than 6 inches asunder from centre to centre. The handrail is to be of the same dimensions and form as shown upon the drawings, having sockets cast on the under sides to receive the tops of the palisade bars; and it is to be screwed to the top of every sixth palisade bar, with a counter-sunk headed screw, and it must be secured or connected with the pedestals in the manner shown upon the drawings. The pedestals are to be of the same dimension and form as shown upon the drawings, having sunk panels on the front and back; internal flanges to be cast on the top to receive the handrail, and the caps are to be put on with counter-sunk headed screws. Brackets are also to be cast on each side of every sixth palisade bar, of the same form as shown upon the drawings, and secured by screw-pins to the plinth.

"The covering or road-plates are to be reticulated, and of the same dimension and form as shown upon the drawing, having flanges cast on their under sides to receive the bearers or tops of the spandrils; they are to be secured to the top of the centre spandrils, and to the flanges cast on the top of the outside spandrils, by 1½ inch wrought-iron screw-pins, two in each joint. They are also to be connected to each other by flanges cast on their under sides, and two 1½ inch wrought-iron screw-pins in each joint.

"None of the castings are to be run from the blast-furnace, but the whole work must be made from good No. 2 pig-iron, of a quality satisfactory to the surveyor or surveyors of the works of the county of Stafford. All the screw-pins, nuts, washers, keys, cotters, wedges, &c., are to be made of the best malleable iron. All the joints are to be made in a good workmanlike manner; and the whole of the work must be fitted and fixed at the contractor's works, and inspected by the county surveyor previous to its being sent off. All the work must be moulded, wrought, fitted, and erected, in a substantial and workmanlike manner, and to the entire satisfaction of the county surveyor or surveyors.

"The contractor must find and pay for all patterns, materials, tools, cement, tackling for fixing his work, and all other utensils or requisite things connected with the construction and fixing his part of the work. The estimates are to be given in a gross sum, and must include carriage of all materials to, and fixing the work at, the place of the intended erection.

"The county of Stafford will be at the expense of the whole of the masonry of the abutments, and cutting and letting in the iron-work into the masonry, and will also provide centering for turning the arch.

"Should any alteration be made hereafter in the dimensions or method of executing any part of the work, the extra price or deduction, whichsoever it may be, shall be agreed upon by the contractor and the county surveyor or surveyors, before such part or parts of the work are put in execution. But such alterations shall only be considered as affecting the matter or object thus specified, and not have any tendency to annul the general contract.

"The whole of the works are to be under the superintendence of the surveyor of the public works of the county of Stafford, or of such surveyor or surveyors, person or persons, as the justices assembled in quarter sessions shall at any time hereafter appoint. And should it appear, at any time during the execution of the works, that the contractor is neglecting, or doing any part contrary to the true spirit and meaning of this specification and drawings attached, then the magistrates shall have it in their power to take it out of his hands, and employ any other person or persons to complete it; and what money may remain due to him shall remain in the hands of the treasurer of the public stock of the county of Stafford till the whole work is completed; and any loss that may be sustained through the neglect or misconduct of the said contractor, to be paid for out of it.

"The whole of the work must be delivered, fixed, and completed, on or before the day of in the year

"The bridge was erected in the year 1830. The total weight of iron-work, which was executed by the Colebrook Dale Company, was 340 tons.

The whole cost of the bridge was as follows:—

Iron-work, delivered, fixed, and completed . .	£3,800	0	0
Masonry	3,193	0	0
Foundations, which were piled according to the most approved method; and the approaches, which are of considerable length and height	2,500	0	0
Total, ...	£9,493	0	0

We come now to the erection of one of the most celebrated structures in the world—the iron bridge over the river Thames—Southwark Bridge. This splendid work crosses the water between London Bridge and Blackfriars. The spot seems to have been well selected, and great improvements and alterations, particularly on the Surrey side, have taken place in consequence of its erection. Southwark Bridge was built in compliance with an act of parliament obtained by a company of proprietors in the year 1811, but not without great opposition on the part of Sir William Curtis and others. The first stone of the south pier was laid by Lord Keith, on the 25th of May, 1815, who, with the gentlemen of the committee of management, partook of a cold collation on a temporary bridge erected on the works. On the 7th June, 1817, the Right Honourable Matthew Wood, as Lord Mayor, laid the first stone of the northern abutment, and the works were then carried on with great energy. The whole was completed in something less than five years, and opened to the public at midnight, in April, 1819.

The arches of this gigantic edifice are of the largest span of any known to exist. The soffits consist of solid masses of cast-iron, of a depth similar to the voussoirs of a stone bridge, and exhibit the first instance in which such a bold plan has been carried into effect. The middle arch rises 24 feet, with a span of 248 feet, and is 4 feet wider than the famous iron bridge at Sunderland. It is composed of eight ribs, riveted to diagonal braces; each principal rib being 6 feet deep at the top of the arch, and gradually extending to 8 feet at the abutments, or parts that rest upon the stone-work. Its whole height above low-water mark is 55 feet to the roadway. The other arches are similarly formed; the span of the two side ones being 210 feet. The abutments are of solid masonry, laid in radiating courses, with large blocks of Bramley-fall and Whitby stones. Vertical bond was adopted, running through every two courses at intervals, thereby giving to the whole mass a solidity perfectly immovable. The masonry of the piers, in like manner, was carried up with horizontal and vertical courses to the springing of the arches; from which points they radiate in a wedge-like form. These piers are 60 feet high from the bed of the river to the top of the parapet, and 24 feet in breadth. The foundations of this bridge were laid in coffer-dams, which were of necessity made very strong, from the irregularities of the bed of the river at this spot. The dams were elliptical in form, and were constructed of three rows of piles of whole timber. In the spaces occupied by the base of the masonry of the piers, a row of whole timber sheeting piles were driven all round the outer edge of the offsets, making, as it were, a square internal dam. These piles, while they formed a secure barrier to the foundations of the piers, acted as a powerful auxiliary to the main dam in securing its base. The centerings on which the arches were turned were of very ingenious construction; and with such skill was the whole work designed and carried into execution, that the settling of the centre arch was only 1 inch and 7-8ths. The bridge is 718 feet long between the abutments, and 42 wide between the parapets. The width of the roadway is 28 feet, with footways 7 feet wide on each side. The weight of metal in the centre arch is 1,665 tons; in the side arches, 2,928. The total weight of iron in the whole structure is stated to be about 5,780 tons.

This noble bridge was designed and executed by the celebrated Rennie. The whole of the iron castings were made at the extensive works of Messrs. Walker and Company, at Rotherham, and there put into arches before being shipped to London. The masonry was executed by Messrs. Jolliffe and Banks. The cost of the whole, including its connecting avenues, amounted to nearly £800,000.

Iron bridges had, about this time, also attracted the attention of the French engineers; and the following description of the Pont des Arts at Paris will be interesting, not only from its being the first iron bridge erected in France, but also from its presenting much novelty of design.

The Pont des Arts was designed by M. de Cossart, the inspector-general of roads and bridges, but some variations were afterwards made from the original design by M. Dilon, to whom the execution of the work was intrusted.

The bridge is a nine-arched structure, the width between the piers measuring between 56 feet 9½ inches, and the thickness of the piers themselves, 6 feet 4½ inches above the footings. Each arch consists of five ribs, 7 feet 11¾ inches apart from centre to centre, each rib forming a large cast-iron arch, 6⅜ inches in depth, and 3 $\frac{8}{16}$ inches in thickness, formed of the two beams meeting at the crown of the arch. The extremities of the arch rest on skew-backs of cast-iron, embedded in masonry at the top of the piers. The chord of the arc measures 60 feet 8¾ inches, and the versed sine 10 feet 8 inches. The smaller arches of iron are turned over the piers springing from the haunches of the adjacent principal arches, and supporting the roadway above the piers. Upright supporters are carried from the centre of the piers to the crown of the small arches, and are strengthened by struts supported on the larger arches. The ribs of each arch are bound together by tie-rods fixed to the top of the large arches. At first, the upright supports of the smaller arches were connected by only one cross-piece, and had no braces in the

upper part; but owing to the visible effect produced upon the bridge by a large number of persons crossing suddenly from one side to another on the occasion of some public spectacle, it was deemed expedient to insert additional braces. The general appearance of the bridge is very good—especially for a foot bridge—for which purpose it is admirably adapted. It is of exceedingly light and elegant appearance, as also of skilful and scientific construction, and would form an excellent model for a bridge not subject to any great strain.

Iron arch-bridges of various dimensions have, since the completion of the great works we have described, become so numerous, that it is impossible, as indeed it is unnecessary, to describe or enumerate them. With the extension of railway works, however, it became apparent that some modification of the ordinary form of those bridges was desirable. It is well known by persons conversant with railway matters, how much trouble engineers have to encounter in arranging the crossings of the numerous roads, &c., by which a line of railway is intersected in its course over an extent of country. Either in passing over or under the line, there is frequently great difficulty in obtaining sufficient height, or "headway," as it is termed, for the railway trains to pass under the road-bridge, as in the former case, or for the road traffic to pass under the railway, as in the latter case. As the legislature imperatively requires a certain headway should be given, and will not permit any alterations in the levels of roads which shall increase their acclivities beyond a certain extent, immense expense has been entailed on railway companies in fulfilling all these required conditions.

The desideratum for railway-bridges then was the means of adapting iron to the construction of bridges perfectly flat, or in which might be preserved the minimum distance from the under side, or soffit of the girder, to the level of the roadway above. Bridges of this kind, it is true, had been built of timber, that is, simply of horizontal beams laid across the opening to be spanned; but the application of cast-iron girders in the construction of bridges, had as yet been made only to those of very limited span. For, the maximum length of bearing to which single cast-iron girders, liable to be loaded with heavy weights, could be safely applied, having been commonly taken at 40 feet only, it followed that the use of these girder bridges was necessarily much restricted. The convenience of this form of structure, however, was so obvious, and so desirable was it to extend its application to bridges of larger span, that attempts were continually made to combine in every variety of construction wrought-iron with cast metal, in such a manner as should impart to the compound structure the power to resist the extension of wrought-iron itself. A paper, by Mr. John Storey, describing an ingenious mode of so combining malleable iron bars or rods with cast-iron girders, and thus forming as it were a kind of metal trussing, was read at one of the meetings of the Institution of Civil Engineers.

The author states, "that his attention has been long directed to the extensive construction of the brick and stone bridges usually erected over and on the line of railways, and the apparent want of durability in the timber-bridges, which have in some instances been substituted; as well as to the cast-iron bridges, which have generally been constructed in situations where the height between the top of the rails and level of the roads which they span, were so limited, as not to admit of a stone or brick arch. In the latter case, cast-iron girders have been employed, but their great weight has rendered them expensive, and has obliged the abutment-piers for supporting them to be very substantial.

In order to obviate these objections, the author has introduced combinations of cast and wrought iron in forms which he contends may be advantageously adopted for occupation-bridges, or even for carrying the railway, and that they may be constructed at a less cost than stone, brick, or even timber bridges. These bridges consist of longitudinal and segmental girders of cast-iron, abutting against each other at the ends, secured together by bolts and nuts through the flanges, and resting on masonry abutments; a system of wrought-iron tie-trussing is then applied, and struts are placed at certain distances where they are requisite. As many of these principal trusses are used as the strength of the bridge demands, and they are connected by transverse braces, and distance-pieces of cast iron, thus preventing undue outward pressure, sockets are cast upon the girders to receive the timber joists, and the platform is covered with Dantzic deal planking spiked to the joists. The wrought-iron struts at the top, clasp the girders, to which they are also firmly bolted, and their lower extremities pass through the truss, so that on the nuts being screwed up, the truss is brought to its proper degree of tension, and being made sufficiently strong to bear the weight calculated for the bridge, independent of the segmental girders, the weight and strain are brought upon the abutments in the most favourable manner. Bridges thus constructed do not require any centering for their erection, as each side may be put together near the spot, and, by means of purchases, may be lifted entire on to the abutments, or the whole bridge may be put together before the earth is excavated from between the abutments, excepting only as much as is necessary for receiving the trussing.

The dimensions are given of occupation-bridges calculated to bear 8 tons, which is stated to be a greater weight than is required by the land-owners. The total weight of cast and wrought iron in an oblique bridge of a span of 86 feet 3 inches, and 11 feet wide, is 11 tons 7 cwt., and that of a square bridge of 106 feet 6 inches span and 11 feet wide, is 14½ tons; their total cost, including excavating the ground, the masonry, stone penning on the sides of the excavations, the timber-work, and the painting, was for the former £280, and for the latter, £342; these sums are stated to be much less than the expense of similar bridges of stone, or even of timber.

A design is also given of a stronger kind of bridge of similar construction, for carrying two lines of railway. The span is 90 feet, and the width 22 feet between the side railings. The weight is 43 tons, and the total cost, including the masonry, is estimated not to exceed £1,200. It is calculated to bear about 50 tons, which is as much as could be brought upon it by any passing train.

Numerous railway-bridges have been erected within the last few years, in a similar manner to that suggested by Mr. Storey, and also by other engineers. Many of these designs show much ingenuity, and great variety of arrangement, and exhibit almost every form of combining wrought with cast iron. A bridge of a very novel construction, however, requires particular notice, not only from the boldness of its design, but from its being, we believe, the first application of the suspension principle to a railway-bridge.

The iron tie-bridge over the Regent's Canal at Camden Town, on the line of the London and Birmingham railway, is one of the most ingenious structures on the whole line, and was designed by Mr. Fox, one of the resident engineers, for the purpose of conveying the railway at an elevation of only 13 feet above the surface of the water, and with a span of not less than 50 feet. The structure consists of three main cast-iron ribs, each composed of two large castings, extending the whole width of the opening, and having a bearing at each end of 4 feet. These minor ribs are connected together by transverse iron bracing. The pedestals on which the ribs take their bearings, are 10 feet long, 6 feet wide,

and 30 feet high, and are built of brick and stone, founded on a bed of concrete 2 feet in thickness. Eight cross girders run from either side main rib to the centre main rib, from which they are severally suspended at each end by vertical rods and keys. The girders are of fish-bellied form, and are each 28 feet in length, and 2 feet deep in the middle. The thrust of each arch is sustained by wrought iron tie-bolts running from end to end of the ribs. To the front of the ribs is bolted open ornamental work, which gives to the whole a pleasing appearance. The extreme width of this bridge is 60 feet. The rails over the bridge are set in chairs, and bolted thereto. The chairs are fixed on oak slabs running longitudinally, and resting on the tops of the girders. The side and intermediate spaces, and also the space beneath each pair of rails, are covered with iron gratings, furnished with flanges underneath to strengthen them.

A good example of cast-iron compound girder bridge trussed with malleable iron bars, was erected some years since over the river Lea, on the line of the Northern and Eastern railway. This bridge is formed with girders, each girder being 70 feet long, and made of two castings, joined at the centre by bolts passing through vertical flanges. Upon the meeting ends of the two castings, are cast dove-tailed projections, or bosses, with wrought-iron clips fixed over them.

"These bosses give additional security to the joinings of the castings. Each girder is perfectly horizontal from end to end, and the top and bottom lines parallel. The girders are 36 inches in depth, with bearings on the abutments of 2 feet at each end; the clear span between bearings being 66 feet. The sections of the castings shows a vertical rib, and projecting flanges at top and bottom. The truss bars are arranged in sets of 4 bars on each side of the girder, and pass obliquely downward from the top of the girder over the bearings at either end, to the under side of the girder, at a distance of about 11 feet short of the centre. The space between of 22 feet has horizontal truss-bars passing beneath; both horizontal and oblique bars are secured by bolts or pins 3 inches in diameter, passing through projecting saddles under the lower flange of the girders. The bars at their upper extremities pass through sockets cast upon the girders, and are keyed through them."

It would be easy to multiply examples of iron bridges, many of them possessing great merit; but the lamentable failure of some large bridges of this construction, has, within the last few years, led to the conclusion, that some radical defect existed in these compound constructions.

This defect evidently consists in the impossibility, in structures of this kind, of connecting wrought and cast iron in such a manner as to bear equally the strain of such a load as a railway train, passing over at a high velocity. This became fatally apparent in the failure of the largest bridge of this kind, erected over the river Dee, near Chester, and on the line of the Chester and Holyhead railway.

"This bridge, which crosses the Dee at an angle of 48 degrees, consists of 3 spans or bays, each 98 feet wide in the clear, the three series of girders forming the bridge being supported on two abutments of masonry, one at either end, and two intermediate piers. The width of the bridge is formed by 4 of these girders, placed parallel to each other, in 2 pairs, one roadway or railway being supported between each pair of girders, and formed of 4-inch planking laid upon transverse balks of timber, which rest upon the bottom flange of the girders. The girders are secured transversely from moving outward or away from each other by tension-bars, fitted at the ends to dove-tailed sockets, cast upon the girders. The entire bridge thus comprises 12 girders, each having a clear span of 98 feet, and a total length of 109 feet; that is, including a bearing at each end of 5 feet 6 inches in length. Each of these girders, 109 feet long, is composed of three castings, or lengths, having a uniform vertical depth of 3 feet 9 inches. The dimensions of the section are as follow:—vertical rib or web, $2\frac{1}{8}$ inches thick; top flange, $7\frac{1}{2}$ inches wide, and $1\frac{1}{2}$ inch thick; bottom flange, 2 feet wide and $2\frac{1}{2}$ inches thick. The sectional area of the top flange, including the moulding, is equal to 14 square inches; of the bottom flange, including the moulding, 66 square inches; and of the rib, 80 square inches; making a total uniform sectional area of 160 square inches. The joints of the three castings, in each girder, secured by wrought-iron bolts, passing through flanges, are strengthened by additional cast-iron joint plates, 3 feet deep at the centre, over the joint, and 13 feet in length, bolted to and scarped over the top flanges of the castings, over a length of 6 feet 6 inches upon each; dove-tailed bosses, cast upon the lower flanges, are also secured with clips of wrought-iron.

"The total depth of the girders, at each joint, is thus increased to 6 feet 9 inches. Similar plates of half the length of those over the joints, are also bolted over the ends of each compound girder; and the vertical inclination of the truss-bars, from the top of the girder at each end of the bottom of it at the joints, is thus increased to about 6 feet. The malleable iron truss-bars are arranged in sets of 4 each, 1 set on each side of the girder, each bar being 6 inches wide and $1\frac{1}{4}$ inch thick, put together in lengths or long links, similar to those used for suspension bridges, and secured by bolts at the joints of the girders, passing through the cast-iron girder and the 8 wrought-iron bars. The upper ends of the bars are secured with wrought-iron keys, driven through the bars and the casting, so as to tighten them well up in their position. By the great length of the girders, and the comparatively small depth thus afforded for the trussing, the action of the bars is reduced to nearly a horizontal direction, and their power to avert deflection in the girders is thus much diminished. Besides this, it must be remarked, that the sectional area of the bars is much less when compared with the total length of each girder, than in all smaller structures on this principle; and the relative effect of any increase of temperature in extending their length, and thus reducing the effectiveness of their assistance, is similarly augmented."—*Dempsey, Treatise on Iron Girder Bridges.*

The failure of one of these girders was ascribed to various causes, and much discussion on the subject took place at the time; but to whatever the accident in this particular case might be attributed, the inherent weakness of such combinations of wrought and cast iron became perfectly clear.

The attention of the government having been for some time past, by this and similar failures of iron girder bridges, directed to the subject, a commission was at length appointed to inquire into the whole question of the application of iron to railway structures. In the evidence given before this commission, will be found an immense mass of valuable information, obtained under all the advantages of a Board so appointed; and although in their report the commissioners do not express any very decided opinion on the merits of the various forms of construction so strongly recommended to them, there is much practical knowledge to be gained by a careful perusal of the evidence and examination of the ingenious plans attached to it. We shall now proceed to give some extracts from this report:—

"The simplest bridge," observe the commissioners, "and that which admits of the greatest possible headway at a given elevation, is, undoubtedly, the straight girder bridge.

"The length of a simple cast-iron girder appears to be limited only by the power of making sound castings, and the difficulty of moving large masses. Thus the practical length has been variously stated to us as 40, 50, and 60 feet. The form resulting from Mr. Hodgkinson's former experiments on this subject is universally admitted to be that which gives the greatest strength, but the requirements of construction compel many variations from it, especially in the ratio between the top and bottom flanges. Moreover, the convenience and the necessity of keeping the roadway for rails as low as possible, has introduced a practice of supporting the beams which sustain the rails upon one side of the bottom flange. The pressure of the roadway and of the passing loads being thus thrown wholly on one side of the central vertical web of the girder, produces torsion (which is not always taken into account in determining the proportions of the girder.) The existence of this torsion is admitted on all hands, and various schemes are employed to counteract and diminish it; but the form of a girder that will effectually resist this disturbing force without incurring other evils, still remains a desideratum.

The requisite length of girders is increased considerably by the excessive use of skew bridges, and it is much to be regretted that difficulties should often be thrown in the way of altering the course of existing roads and canals when the line of a proposed railway happens to cross them at an acute angel. Partly from these causes, and partly from a little indulgence in the pride of construction, skew bridges may be found, of which from the obliquity of the bridge, the girders are more than double the length that would be required by the direct span of the opening to be crossed.

When the span of the opening, or other circumstances, render the use of single straight girders unadvisable, straight girders built up of several separate castings bolted together, and sometimes trussed with wrought-iron tension rods, are largely employed, and necessarily with great varieties of construction. By these means the girders may be extended to spans of upwards of 120 feet.

When wrought-iron is combined with cast-iron in the manner of trussing, several difficulties arise from the different expansions of the two metals, and the difference of their two masses, which causes the wrought-iron rods to be more rapidly effected by a sudden change of temperature than the cast-iron parts. The constant strain upon the wrought-iron tends to produce a permanent elongation, and hence tension-rods may require to be occasionally screwed up. We have sought for opinions and information upon all these questions, and these show that the greatest skill and caution is necessary to insure the safe employment of such combinations. It is not admitted that the vibration of railway trains would loosen or injure the bolts or rivets of compound girders. Nevertheless, wood, felt, or other similar substances, have occasionally been introduced between surfaces, to diminish the communication of vibration.

The general opinion of engineers appears to be, that the cast-iron arch is the best form for an iron bridge, when it can be selected without regard to expense, or to the height above the river or road which is to be crossed. For low bridges the bowstring girder is also strongly recommended. Lattice bridges appear to be of doubtful merit.

We come now to the description of that new mode of construction introduced by Mr. Stephenson and his able coadjutors, and perfected in the magnificent structures to which the public attention has been so long directed, the Conway and Britannia tubular bridges:—

The application of iron in this form of bridge consists in the riveting together boiler-plates as in iron ship-building, combined in various ways with cast-iron. Hollow girders are thus formed, which are either made so large as to admit of the road and carriages passing through them, as in the bridges above described, or else these tube girders are made on a smaller scale, and employed in the same manner as the ordinary cast-iron girders, to sustain transverse joists which carry the road. The first kind is applicable to enormous spans, those of the two bridges above-mentioned being 400 and 462 feet respectively. The second kind are said to be cheaper and more elastic than other forms, for spans that exceed 40 feet. These methods appear to possess and to promise many advantages, but they are of such recent introduction, that little experience has yet been acquired of their powers to resist the various actions of sudden changes of temperature, vibrations, and other causes of deterioration. The eminent engineers examined before the commissioners, however, very generally expressed opinions favourable to the tubular form of bridge.

Before proceeding to describe the Britannia and Conway Bridges, it may be desirable to give a slight sketch of the circumstances which led to their erection:—

In the session of 1844, a Joint Stock Company proposed to parliament to undertake the construction of a railway from Chester to Holyhead, in continuation of lines already made. The bill introduced for this purpose contemplated the use of Telford's celebrated suspension bridge over the Menai straits, as the means of conveying across the railway, carriages and waggons, divested of the ponderous locomotive engine. The Commissioners of Woods and Forests, however, who had the jurisdiction of the bridge, would at first only consent to this proposal as a temporary measure, and afterwards objected to its being made use of at all. The company not being prepared with any plan for a permanent bridge, were obliged to content themselves with an act of parliament which gave them power to construct a railway from Chester to Bangor, and through the Isle of Anglesea to Holyhead, leaving an hiatus of five miles at the Menai straits. The means of filling up this break was reserved for future consideration, and for a permanent bridge to be sanctioned by the act of a subsequent session. In the following autumn, Mr. Robert Stephenson, the engineer of the company, prepared plans for a cast-iron bridge of two arches, each having a span or clear width of 350 feet. The height of each arch was to have been 100 feet at the crown, and the total cost of the bridge would have been £250,000. The Britannia rock, about a mile to the west of the suspension bridge, was selected as the most eligible point for crossing the straits; but in consequence of the rapid current, and other circumstances of difficulty which exhibited themselves at this point, added to the necessity of interfering as little as possible with the navigation of the straits, Mr. Stephenson proposed to build the arches of this bridge, not upon supports from beneath, as is usually done, but by stringing on, as it were, a series of iron blocks or vertebræ from each pier, until they should meet in the middle, in a way somewhat similar to those which had been proposed in former years by Mr. Telford and Sir J. Brunel. The railway company made their application to parliament in the session of 1845, in order to obtain power to construct this bridge. The company, however, found themselves strongly opposed, not only by parties interested in the navigation of the straits, but by others whose interest lay in driving them to Port Dynllaen. An appeal was then made to the Lords Commissioners of the Admiralty, as conservators of the navigation, and after a lengthened inquiry, the bridge proposed by Mr. Robert Stephenson received their lordships' veto, and a form of structure was prescribed, which should leave a clear opening of not less than 450 feet over each of the two navigable channels on each side of the Britannia rock, with a height of 105 feet above high-water over 370 feet of that

opening, the remaining 80 feet being allowed to have less height, so as to admit of the construction of an arch of that form, should it be desired by the company.

It was this that led to the grand and untried design of the present rigid wrought-iron tubular bridge, which Mr. Robert Stephenson, after great thought and labour, assisted by Mr. Fairbairn, Mr. Hodgkinson, of the Royal Society, Mr. Edwin Clarke, the engineer of the works—gentlemen well known for their mathematical and scientific attainments—matured. The entire length of the stupendous structure is 1,841 feet from end to end, consisting of four large sections, the two side-tubes being each of them 230 feet long, and the two middle ones 460 feet each. When originally proposed before the committee of the House of Commons, the plan was received with general incredulity. The word "tube," it may here be observed, is not one of the best epithets that could be used to describe the structure, seeing that the bridge, instead of being round, is a perfect square. Though almost a misnomer, the name arises from the circumstance of the experiments that were to decide the form of the bridge, having been made with cylindrical, elliptical, and rectangular tubes; but in reality, the structure, as it now rests on the banks of the Menai, the site of its construction, is one immense closed-in iron corridor, forming a horizontal iron gallery or passage, within which the rails for the trains are to be placed, and 450 feet in length. It is hollow from end to end, and would, if filled with shops, and lighted by sky-lights, make a Burlington Arcade.

A structure of this kind, though on a rude and miniature scale, appears to have existed for years on the Cambridge line of the Eastern Counties Railway; and Mr. Stephenson, the originator of it, amplifying upon this, designed the present tube. A long series of experiments, by engineers and mechanics fully conversant with such researches, were made, directed to the ascertaining—divested of all preconceived ideas—the strongest form for a sheet-iron tubular bridge; and the inquiry, in addition to the more immediate object it had in view, has been of immense public service in determining the strength of the materials used in the formation of railways. These experiments have been extremely laborious, and very costly. In the course of them, the remarkable fact has been disclosed, that the power of wrought-iron to resist compression is much less than its power to resist tension, or exactly the reverse of that which holds with cast-iron; and the important fact has also been arrived at, that rigidity and strength are best obtained by throwing the greatest thickness of material on the upper side. While the cylindrical tube, with a given weight, was ruptured by tearing asunder at the bottom, the elliptical showed weakness at the top: both were consequently discarded; and the rectangular tube, which indiacted strength of a higher order, and greater rigidity, was adopted. The result of every recent experiment on this species of structure, on a small scale, over the Conway, are very interesting, as confirming the accuracy of the original calculations. Measured by a cord-line in the inside of the tube, formed by the axis of a powerful telescope fixed to its side, the deflections have been made with a weight of 52 tons, 0·48 inch; 112 tons, 0·98; 173 tons, 1·30; 235 tons, 1·47; and on the removal of these loads, the tube has recovered its rigidity in ten minutes. The tube is constructed to bear, in addition to its own weight, 2,000 tons, a load ten times greater than it will ever be called upon to sustain. The deflection caused by trains and locomotives passing at full speed is very slight. A weight of 300 tons has produced a deflection of 3 inches. A very remarkable phenomenon is connected with this huge mass of iron of 1,600 tons, caused by changes of temperature in the weather, which affect it like a thermometer. A little sunshine raises the centre an inch, and produces a horizontal deflection of an inch and a half.

Its great length, and the nature of its material, so sensitive to temperature in the peculiar form that it takes, causing it to expand .0001 of its length, or ½ an inch for each increase of 50° of Fahrenheit, and contracting in the same ratio, is the assigned cause of its being such a delicate thermometer. Alternate sunshine and showers of rain cause these tubes to expand and contract; and one of them, if placed on end in St. Paul's churchyard, would be 107 feet higher than the top of the cross. It is calculated that the wind, at a velocity of 80 miles an hour—the rate of a hurricane—would only give a total pressure of 128 tons, distributed over the whole side of these tubes.

We have now to describe the means by which this gigantic structure was raised to its present lofty height, and the enormous towers by which it is supported there.

The spot selected by Mr. Stephenson for the site of the bridge, was at that part of the Menai straits where the Britannia rock rises from the bed of the stream nearly in its centre. On this rock is erected a tower of masonry; at the limit of the water-way on either side of it, similar towers; and on the land, on each shore of the strait, beyond the towers, continuous abutments of masonry. The bridge is therefore supported by the Britannia rock in the centre; at 460 feet from it, on each side, by a tower built in the same manner as that on the rock; and at 230 feet from each of these towers, by the land abutments.

The following description of these masses of masonry is taken from a very interesting little work published by Mr. Weale, "*Treatise on Tubular and other Iron Girder Bridges*," by Mr. Dempsey, C. E.

Britannia Tower.—62 feet by 52 feet 5 inches at the base, and reduced by the batter to 55 feet by 45 feet 5 inches at the height of 102 feet above high-water line, at which level the tubes pass through it. A plinth extends round the base of this and the other towers; and the height of this tower above high-water level is 200 feet, or nearly 230 feet from the bottom of the foundation on the rock. The stone used for the external parts of this, and the other towers and abutments, is a limestone of hard and durable quality, known as 'Anglesea marble.' It is quarried at Penmaen, on the shore, and near the north-eastern extremity of the island, and is 'got' in stones of great size, some of them weighing 10 to 14 tons. The interior of this, and the other masonry, is constructed of red sandstone, which is a soft stone, and therefore easily worked. It is quarried at Runcorn, in Cheshire, and is durable for inside work. The solid contents of this tower, if solid, would exceed 575,000 cubic feet, but it is constructed with hollow spaces or chambers within it, and the quantity of stone said to be actually used in it is 148,625 cubic feet of the limestone, and 144,625 cubic feet of the sandstone. The total weight of the masonry in this tower is about 20,000 tons, and about 387 tons of cast iron in beams and girders are built in it.

"The foundations were laid, and the work up to the level of high-water was constructed, during the intervals of tide, no coffer-dam being employed, and thus some months were occupied in laying the first course, which was commenced in May, 1846. The scaffolding used for this and the other parts of the work, was of whole timbers or balks, put together with iron straps and bolts where required, and braced with diagonal half-balks connecting the upright posts. Parallel timbers were laid horizontally on the tops of the posts, and rails fixed upon them, and upon these rails travelling crabs or 'jennies,' were enabled to pass in both directions, to pick

up the stones from the ships, raise them to the required height, and deposit them exactly in their intended places. The stones in the whole of the masonry are left with the quarry or rough face, except at the angles, where they are dressed to a square arris, and in the recesses and top entablature, where they are dressed to a fair face all over."

"*Anglesea and Carnarvon Towers.*—The same dimensions at the base as the Britannia tower, viz., 62 feet by 52 feet 5 inches, reduced by the batter to 55 feet by 32 feet at the level of the bottom of the tubes; height from level of high-water 190 feet, or 10 feet less than the Britannia tower. In architectural design and general appearance these towers exactly resemble the Britannia tower, and they are said to contain 210 tons of cast-iron in beams and girders."

"*Anglesea and Carnarvon Abutments.*—These are also battered similar to the towers, and are 176 feet in length, and of width corresponding to the towers, viz., 55 feet at the level of the bottom of the tubes. The raised part of the abutments, in which the ends of the tubes are supported, are continuous across the railway, forming in fact complete towers, of smaller height than, but otherwise similar to, the towers already described. The remainder of the abutments are built of stone-work externally, but built up internally with longitudinal and cross walls, and intermediate arches of brick-work. Over the two parallel spaces formed between the longitudinal walls, corresponding with the two lines of railway, cast-iron girders are fixed, to support the roadway. The continuations of the abutments are surmounted with parapet-walls of solid masonry and considerable height, each of which terminates at the extremity of the bridge with a projecting pedestal, on which a couchant lion, in the Egyptian style, and of colossal dimensions, faces the approaching visitor, and seems to guard the entrance to the iron wonder behind. Each of these lions is composed of eleven pieces of limestone, and measures 25 feet in length and 12 in height, weighing about 30 tons. 'Repose and dignity' are skilfully blended in the expression, and these lions are probably, in more than one respect, among the *greatest* of the works which the talented chisel of Mr. Thomas is destined to produce.

"The four spaces between the Britannia tower and the towers, and between these towers and the abutments, are, as already described, of two dimensions, viz., two of 460 feet, and two of 230 feet. These four spaces have therefore to be spanned by the iron tubes; and as each tube serves for one line of rails only, 8 tubes are required, 4 of 460 feet net length, and 4 of 230 feet net length: the 4 longer ones being across the water, the 4 shorter ones over the land."

In the completion of the work, however, these several tubes are united together, and (with the short lengths also constructed within the towers, and joined to the other lengths,) forming two lines of tube parallel to each other, each of the length of 1,513 feet, and each line carrying its respective line of rails. The process of building and placing these tubes was conducted as follows:—

The land tubes were constructed in their proper positions, on scaffolding of enormous strength erected for that purpose. The portions of tube intended to occupy the Anglesea and Carnarvon towers, after being completed on the scaffolding at either end, were launched forward to meet the main tubes; while these again were built on the land, floated to the proper place, and then raised by hydraulic presses of immense power, to their destined situation. The method of floating these tubes from the building-stages to the base of the towers, was thus accomplished. Several large pontoons having been provided, they were placed at low-water under the tube to be floated, in such a manner that each end of the tube rested on four of these pontoons. As the tide rose lifting the pontoons, the tube borne by them was also lifted, and safely floated to its proper position, ready to be raised by the hydraulic presses.

The following graphic description, by an eye-witness, of the floating of the first tubes, is too interesting to be omitted. The operations were conducted by Captain Claxton, who, with Mr. Stephenson, and other gentlemen, was on the tube directing the proceedings. "Captain Claxton was easily distinguished by his speaking trumpet, and there were also men to hold the letters which indicated the different capstans, so that no mistake could occur as to which capstan should be worked; and flags red, blue, or white, signalled what particular movement should be made with each. About half-past seven o'clock in the evening, the first perceptible motion, which indicated that the tide was lifting the mass, was observed, and, at Mr. Stephenson's desire, the depth of water was ascertained, and the exact time noted. In a few minutes the motion was plainly visible, the tube being fairly moved forward some inches. This moment was one of intense interest; the huge bulk gliding gently and easily forwards as if she had been but a small boat. The spectators seemed spell-bound; for no shouts or exclamations were heard, as all watched silently the silent course of the heavily-freighted pontoons. The only sounds heard were the shouts from Captain Claxton; as he gave directions to 'let go ropes,' to 'haul in faster,' &c., and 'broadside on,' the tube floated majestically into the centre of the stream. I then left my station, and ran to the entrance of the works, where I got into a boat, and bade the men pull out as far as they could into the middle of the straits. This was no easy task, the tide running strong; but it afforded me several splendid views of the floating mass, and one was especially fine. The tube coming direct on down the stream,—the distant hills covered with trees,—two or three small vessels and a steamer, its smoke blending well with the scene, forming a capital back-ground; whilst on one side, in long stretching perspective, stood the three unfinished tubes, destined ere long to form, with the one then speeding on its journey, one grand and unique roadway. It was impossible to see this imposing sight, and not feel its singleness, so to speak. Anything so mighty of its kind had *never been before; again* it would assuredly be; but it was like the first voyage made by the first steam-vessel, something till then unique. At twenty-five minutes to nine o'clock, the tube was nearing the Anglesea pier, and at this moment the expectation of the spectators was greatly increased, as the tube was so near its destination; and soon all fears were dispelled, as the Anglesea end of the tube passed beyond the pier, and then the Britannia pier end neared its appointed spot, and was instantly drawn back close to the pier, so as to rest on the bearing intended for it. There was then a pause of a few minutes while waiting for the tide to turn, and when that took place the huge bulk floated gently into its place on the Anglesea pier, rested on the bearing there, and was instantly made fast, so that it could not move again. The cheering, till now subdued, was loud and hearty, and some pieces of cannon on the shore gave token, by their loud booming, that the great task of the day was done."

The preparations for performing so important and perilous an undertaking as that of hoisting the enormous fabric, to place it in its permanent position over the straits, were on a scale of immense magnitude. This will be the more readily understood, when it is stated that the total dead weight lifted 100 feet high from high-water mark, was upwards of 2,000 tons, or equivalent to the elevation to that height of upwards of 30,000 men. During the progress of this great work, a general impression appeared to prevail with the public, that

when the tubular bridge was *floated*, the whole operation would be completed; but that, if it may be so termed, was a vulgar error. The floating was nothing more than the launch of the great iron ferry to the precise site, where it was to be raised by mechanical power, specially constructed for the purpose, to a height nearly equal to that of the dome of St. Paul's. The stroke of the hydraulic presses employed for the purpose, was 6 feet, that is to say, they were only capable of raising 6 feet at one lift. The tube of 2,000 tons weight was consequently to be sustained while the presses were lowered, and a fresh hold obtained. This sustentation, owing to the immense magnitude of the labour, was effected by building up successive layers of masonry at every 6-foot lift, under the tube, to support it securely in its upright ascent, during which arrangements were made for another 6-foot hoist, until the whole 100 feet were finished. Had it not been for this process of building up, the operation would have only occupied about a day, but as it was, it took a fortnight. The precaution was adopted by Mr. Stephenson and Mr. Clark, to guard against the probability of casualty, seeing that, should any accident occur, the labour of years, and the outlay of half a million of money, would have been inevitably sunk. To insure security, however, some contrivances were adopted, by which the supporting chains, as they rose, were continually followed up by wedges of wood, so that in the event of any accident having arisen to the lifting machinery, no injury, it was expected, would happen to the tube. The mechanical contrivances for the purpose were the largest in the world, and the most powerful ever constructed.

We are enabled, from a close inspection, to give a description of the vast apparatus for hoisting the huge burden. The machine used to effect this, was an enormous hydraulic press, a contrivance invented by Bramah, and used in operations where intense pressure is required. Its construction was of the most simple character, and consisted only of an exceedingly thick and very heavy iron cylinder, like a mortar. A strong piston, or plunger, also of iron, called the ram, and fitted with a leather collar at the shoulder, so as to render it water-tight, worked up and down inside this cylinder. Water was forced into the cylinder by a force-pump, through a small orifice which might be compared to the touch-hole of a gun. The whole secret of the immense power of this machine, consisted simply in the prodigious force with which the water was driven into it, and which in the present instance was so great, that it threw the water to the height of nearly 20,000 feet, which is more than five times as high as the neighbouring noble pinnacle of Snowdon, and 5,000 feet higher than the monarch of mountains, Mont Blanc. It in fact resembled the piston of a steam-engine, but instead of using steam at 30 or 40lb. pressure to the inch, water was used at a pressure of 800 or 900lb. The cylinder of course was of almost adamantine strength, to enable it to sustain and withstand that pressure. The sides of the largest of these presses used in raising the bridge, were 11 inches thick. The weight of the cylinder, which was of cast-iron, in one piece, was 16 tons alone; but the whole machine complete was 40 tons. The ram or piston within it, was 20 inches in diameter, and when worked to its utmost power, would alone be quite capable of raising one of the tubes. The marvellous thing above all was this, that in spite of its immense proportions, its stupendous action was guided and controlled with the most perfect ease and precision by one man. This hydraulic giant was constructed by Messrs. Easton and Amos, engineers of Southwark. It stood on two beams on a lofty sort of eyrie, at the top of one of the towers, whence a grand and open view is obtained of the straits seaward, while its elevation above the ravine was upwards of 200 feet. The press was composed of wrought-iron plates, riveted together at the top of the side towers, where, with its assistant machinery, it occupied a large chamber to itself, about 29 feet above the level to which the bridge had to be raised.

The sensations experienced on looking down from this lofty elevation over the rushing stream of the straits, and the great tubes and machineries strewn round about below, were of a peculiarly impressive character. In addition to this large press, there were two smaller presses, with rams 18 inches in diameter, placed side by side at a similar level on the Britannia tower, and which acted in conjunction with the large press. The chains by which the power exerted by these presses in their lofty position was communicated to the tubes lying at the base of the tower, resembled the chains of an ordinary suspension-bridge, and were similar to those of the bridge at Hungerford. They were manufactured by the patent process of Messrs. Howard and Ravenhill, of London, and consisted of flat links seven inches long, one inch thick, and six feet in length, with an eye at each end, and were bolted together in sets of eight and nine links alternately. The weight of the chains employed in lifting the 2,000 tons, was about 100 tons, far exceeding that of the well-known equestrian statue of the Duke of Wellington at Hyde Park, which has hitherto been regarded as one of the greatest "lifts" of the age. These chains were attached to the tube at two feet from the end, and in order to get sufficient purchase at the part, three strong frames of cast iron were built into each end of the tube. The innermost frame only stiffens and supports the sides, while the tube was resting on its ends. The two outer frames were the lifting frames. The chains were attached to them by three sets of massive cast-iron beams, placed across the inside of the tube, one above another, their ends fitting under deep shoulders or notches in the lifting frames, where they were secured by screw-bolts. As an additional precaution, two very strong wrought-iron straps passed over the upper pair of beams, and descended into the bottom cells beneath the frames, where they were strongly keyed. The weight of these lifting frames and cast-iron beams was 200 tons, and it was even a matter of wonder among the engineers themselves, how machinery could be made strong enough to raise the ponderous load. The way in which the chains were connected with the press, was by an exceedingly thick and heavy beam of cast-iron, strengthened by wrought-iron ties across the top. It rested like a yoke on the shoulder of the ram, and was called the cross head of the press. The two chains passed through square holes at either end of the cross head, and were securely gripped at the top of it by an apparatus called the *clams*, consisting of two strong cheeks of wrought-iron, drawn together by screws like a blacksmith's vice. The beams on which the presses stood, the cross heads, and all the parts that were subjected to a very heavy strain, were either constructed of, or strengthened by wrought-iron, which was found to be less brittle and more trustworthy than cast-iron. As the tube was 12 feet longer, allowing 6 feet at each end, than the distance between the towers in which the presses worked; recesses or grooves were left in the face of each, of 6 feet deep, in order to receive the additional length, and of sufficient width to allow the end of the tube to slide up easily within them. The recesses extended from the bottom of the towers to nearly the height of the hydraulic machines. It was in the low end of these recesses, on a soft bed of timber placed to receive it, that each great tube rested, after being floated there, until the vast mechanical equipments for ballooning it to its per-

manent level, 102 feet above high water mark, were completed.

The entire completion of this celebrated structure, the wonder and admiration not of a kingdom only, but of the world, perfects the communication between England and the sister country. The interchange of transit, and conveyance of correspondence between their respective capitals, may be daily within the compass of ten or twelve hours. This rapidity of locomotion in the present day may be well contrasted with the slow doings of former times. In 1685 it took the then Lord Clarendon, at that time Lord-Lieutenant of Ireland, from six o'clock in the morning to three in the afternoon, nine hours to get from Conway to Bangor, a distance of 14 miles, while a short time since the distance was accomplished by the present Lord Clarendon, Lord-Lieutenant of Ireland, in exactly twenty minutes. At the same period it took a king's messenger, "by express," six days to get over the ground now traversed between London and Chester, 188 miles, in five hours; and it is but twenty years since, that the same distance by coach took more than twenty-four hours.

These are the immediate advantages; the prospective ones consist in the completion of the great harbour of Holyhead, now being constructed for the Admiralty by Mr. Rendel the engineer, the pier at which is completed, and the breakwater for commencing the vast operations fixed. Should the Admiralty, as has been long expected, on the completion of this harbour, remove to it the West India packets, now starting from Southampton, and the Galway line of railway be finished, the voyage to the United States by this route would be shortened four or five days.

We cannot close this article, and necessarily imperfect account, of the Britannia bridge, without a passing allusion to the unfortunate *difference* that occurred during its progress, between Messrs. Stephenson and Fairbairn. It is greatly to be lamented, that men so eminent for talent should differ as to their respective claims to the conception and execution of so grand a work. It is not for us to presume to settle such claims, but surely each possesses in himself merit so surpassing ordinary minds, that he may well afford to yield a portion of honour to the many competitors who may join with him in the race for fame. A work like this might afford distinction for many minds, and varied talents; to all give honour, where honour is due. Let us then award to a Stephenson the merit justly due to him for his original conception; to a Fairbairn, the unwearied perseverance and the vast practical ability, by which that conception was realized and brought to perfection; to all associated in the undertaking, each in his peculiar walk, the merit of talent, zeal, and untiring industry.

Iron Chain, pieces of iron linked together. Iron chains are very serviceable under the roofs of circular buildings, where there is no intermediate tie, particularly at the bottom of stone domes, in order to prevent them from spreading or pushing out the walls, which, without this precaution, might be subject to separation, especially when the dome has to support an immense turret or lantern of stone. The dome of St. Paul's Cathedral, London, has two chains let into a bondage of Portland stone laid for the purpose.

Iron Girders. Girders of wrought and cast iron have now been used for some years in the construction of buildings, but more especially in the formation of railway bridges, stations, &c. The article on iron bridges will show how extensively they have been applied in that way. Various forms of girders have been recommended, and various methods suggested of combining wrought with cast iron, but these improvements have been more directed to the use of girders in the construction of railway and other bridges, than in buildings. Cast-iron beams for warehouses, and other large buildings, have been used with success.

Iron King-Posts and Queen-Posts, are in many instances preferable to those constructed of wood, and are not more expensive where both bolts and straps are used.

Iron Stone, an ore of iron composed of iron combined with oxygen, silex, carbonic acid, and water. When of a superior quality, it yields near 40 per cent. of iron. In Missouri, United States, iron stone has been found yielding 75 per cent. of metal.

Iron Wood, the popular name of some species of a genus of trees distinguished for their hardness. The *diospyrus ebenus*, or ebony, is sometimes called ironwood.

IRREGULAR, in the art of building, a term applied not only to the parts of an edifice which deviate from the proportions established by antique monuments; as when the Grecian-Doric is made more than six diameters in height, the Ionic more than nine, and the Corinthian more than ten; but also to places where the angles are unequal, and to edifices whose counterparts do not correspond in the several elevations.

A column is said to be irregular, not only when it deviates from the proportions of any of the three regular orders; but when its ornaments, whether in the shaft or capital, deviate from the established forms peculiar to the order.

Irregular Bodies, solids not terminated by equal and similar surfaces.

Irregular Figure, a figure whose sides and angles are not equal.

Irrigation, in agriculture, the art of causing water, by artificial means, to be distributed over the surface of the land, to afford moisture to the plants, &c., where insufficiently supplied with it by nature. Of late years a practice has been adopted, and with great success, of irrigating lands situated near large towns with the sewage-water diverted from the sewers, and conveyed by means of pipes to the required spot. The distribution is then effected in various ways, according to the nature of the ground to be irrigated, and other circumstances.

ISAGON, (from the Greek, *ισος*, *equal*, and *γωνια*, *an angle*,) in geometry, a figure consisting of equal angles.

ISIAC TABLE, one of the most considerable monuments of antiquity, being a plate of copper or brass, discovered at Rome, in 1525, and supposed, by the various figures in bas-relief upon it, to represent the feasts of Isis, and other Egyptian deities.

With regard to the history of this monument, we may observe, that the copper or brass ground was overlaid with a black enamel, artificially intermixed with small plates of silver. When, in the year 1525, the constable of Bourbon took the city of Rome, a locksmith bought it of a soldier, and then sold it to Cardinal Bembo, after whose death it came into the hands of the Duke of Mantua, and was kept in that family till it was lost at the taking of that city by the Imperialists, in the year 1630, nor has it been ever heard of since. By good fortune it had been engraved in its full proportion, and with all possible exactness, by Æneas Vico of Parma. This tablet was divided into three horizontal compartments, in each of which were different scenes, containing different actions. These compartments are, as it were, different cartouches, distinguished sometimes by single strokes only, but oftener by a very large fascia, which is full of hieroglyphics, that is, of that mysterious writing, consecrated by the ancient Egyptians to the mysteries of religion. The four sides of the table were enclosed with a border filled up, like the ground, with several figures of the Egyp-

tian gods, and with a great number of the hieroglyphics. There have been various opinions as to the antiquity of this monument: some have supposed that it was engraved long before the time when the Egyptians worshipped the figures of men and women. Champollion judged it to be the work of an uninitiated artist, little acquainted with the true worship of the goddess Isis, and probably of the age of Hadrian. Others, among whom is Bishop Warburton, apprehend, that it was made at Rome, by persons attached to the worship of Isis. Dr. Warburton considers it as one of the most modern of the Egyptian monuments, on account of the great mixture of hieroglyphic characters which it bears.

ISLE. *See* AISLE.

ISODOMUM, a species of walling used by the Greeks. *See* WALL.

ISOSCELES TRIANGLE, a triangle with two of its sides equal.

ISOTHERMAL LINES, curves supposed to be traced on the surface of the earth, so that each may pass through a series of points, at which the mean annual temperature is the same.

ISTHMIAN GAMES: these were one of the four great national festivals of Greece; the others being the Olympian, Pythian, and Nemean. They were celebrated under the presidency of the Corinthians, near Corinth, on the isthmus connecting Peloponnesus with the continent—hence their name,—and were performed at intervals of four years, corresponding with the recurrence of the other festivals above mentioned, so that each year had its solemnity. The Isthmian games were first established in honour of Melicertes, the son of Ino (Paus. i. 44); but were reorganized by Theseus in honour of Neptune, the presiding deity of the Isthmus. The crowns bestowed on victors were of pine leaves. See OLYMPIAN GAMES, and CIRCUS.

ISIS, one of the chief deities of the Egyptians, the sister of Osiris, was represented as the goddess of fecundity, and the cow was therefore sacred to her. She was said to have first taught men the art of cultivating corn. Heads of Isis are a frequent ornament of Egyptian capitals on the pillars of the temples. See EGYPTIAN ARCHITECTURE.

ITALIAN ARCHITECTURE.—A style of architecture prevalent in Italy during the fourteenth and two following centuries, but more especially during the fifteenth, from which circumstance it obtained another designation, being known likewise under the name of the *Cinque-cento* style. The term "Italian" does not include every style and class of building to be found in Italy, but is restricted to that style which was deduced from the ancient Roman or classical manner of building. To attempt to affix to this style anything like a precise or definite character would be perhaps impossible owing to the many varieties of design and different modes of treatment which it exhibits; all we can do is, to give some general notion of the prevailing character of the style.

After the fall of the Roman empire, its architecture declined into a state of semi-barbarism, and degenerated into what is commonly termed the Romanesque style; the cities of Italy were adorned with edifices in either the Byzantine or Lombardic manner, as their intercourse preponderated with Byzantium or Rome. Gothic architecture did not make its appearance in Italy until a comparatively late period, nor even then did it possess any decided or lasting influence; it was, however, in vogue to some extent during the thirteenth century, and, although of a mixed character, may be said to have been the prevailing style of that date. Of the buildings of the Pointed style in existence previous to the revival of the Roman method, the palace of the doge at Venice will form a fair example.

This edifice consists of three stories, the lower two of which are comprised in the lower half of the building. The first or lowermost story contains eighteen simple pointed arches springing from low stunted columns, above which, and forming the second story, is an open gallery of thirty-six small pointed ogee arches having the intrados formed in the shape of a trefoil. In the centre of the upper arcade is a large balcony with tabernacle-work above, to the right and left of which the wall is formed of masonry jointed diagonally, and containing six large pointed windows. In the centre of the building is an attic crowned by statues, and the horizontal cornice is terminated with a pierced battlement.

This style of building was not, however, destined to prevail much longer. At the close of the thirteenth century, a new cathedral was to be built at Florence, and was commenced on a grand scale in A.D. 1298, by Arnulfo di Cambio da Colle, or, as stated by other authorities, by Arnulfo di Lapo. The design of this architect was, at the outset, of an original character, and differed materially from the style then in use; this difference, however, was much increased by the alterations of succeeding architects who where engaged upon the work, amongst whom may be enumerated the names of Giotto, Taddeo Gaddi, Andrea Orgagna, and Felippo di Lorenzo. In 1408, a meeting of architects was called by the citizens, to discuss the best means for completing the cathedral, and it was at this time that Brunelleschi made his bold proposal to raise the dome, and it was he who completely effected the alteration of style. This building, which was of unusual size and magnificence, had great influence in effecting a change of style throughout Italy, and led ultimately to what is called the revival of Roman art. This, however, is not a fair designation of the mode of building prevalent in Italy in the fifteenth century; it was not a re-introduction of the old classic styles, but rather an adaptation of classical details to buildings of entirely different character, disposition, and arrangement. It is true that the artists who introduced this style adopted the classic orders, reduced them to a system, and determined their form and proportions most minutely, yet, nevertheless, applied them in a very different manner to the ancients, and to buildings of entirely different composition. Even in their delineation of the orders, they were guided rather by the writings of Vitruvius, than by existing Roman examples, and endeavoured rather to make the latter agree with the former, than the descriptions of the writer with actual examples.

It would be difficult, as we before observed, to give a definite description of Italian architecture; we can, however, attempt to give some general notion of a few of its leading characteristics. One of the main points in which it differs from purely classical art, is its partiality for fenestration or the introduction of windows, so as to form a marked feature in the design. The employment of lighting apertures had become indispensable, and in some Italian buildings was carried to great excess, so that, what with the windows and the external ornamentation, little space was left of naked walling. Now, the employment of windows, especially to such an extent, at once furnishes us with a feature of very great importance, and it is questionable whether it is not of greater importance than that of columniation: it is at least equally if not more strongly marked. The two systems of fenestration and columniation form two grand distinctions in architectural design, and are in a certain sense antagonistic in principle, nor can they readily be made to harmonize together: for fenestration either interferes with the effect aimed at by columniation, as in the case of a colonnade, where the simple and chaste effect produced by the repetition of a range of columns receding one behind the other, is marred and broken, and the unity of the composition destroyed; or otherwise is reduces columniation to an inferior and secondary position as

a mere means of decoration, to, in short, a mere accessory, as is evidenced in the use of engaged columns, and pilasters, and in the adoption of small columns, &c., for the adornment of only portions of an edifice. The latter is the method resorted to by the Italians, and though it may be said with some reason, that the columnar-fenestrated is an anonymous style, and that the terms astylar and fenestrated ought in practice to be synonymous, yet when we behold some of the beautiful structures raised in this style, we cannot yield ourselves entirely to this opinion. In our idea they may lawfully be combined when one is made clearly and distinctly an accessory to the other, and when the pre-eminence of the one is at once palpable and evident to the senses: but they may not be so employed where they hold equally important positions in the same edifice, one or the other must be ostensibly predominant. The Italians have employed the orders as ornamental accessories, and have been in many instances eminently successful, as far at least as regards the production of elegance and taste in the design; if we were to criticise too severely, and enter into the question of the unity of design and construction, we might not be so well able to vindicate the claims of this style; it will not bear such rough-handling as the Pointed.

In some instances, which are indeed the least removed from the classic in this respect, the entire edifice, or at least the principal portion of it, is comprised in one order, which is thus made to embrace two or more stories of the building, and the same number of ranges of apertures; and sometimes the main body of the building is crowned by a single pediment. This is what some would have us call classical, or at least very nearly classical; but we must confess we do not recognize the resemblance, and if there be a likeness, it is by no means a flattering one. This method would appear to us to be the first bungling attempt at adapting the ancient orders to the altered requirements of that age; such a system can be termed neither the columniated, nor the fenestrated, nor even a combination of the two, for there is no agreement or unity between the two principles so applied; you have them both together, it is true, but not in combination or unity: they are in open war, and, destroying each other's beauties, they are both spoiled—self-destroyed. The two systems are individually too prominent, they jar, and cannot blend together. Besides all this, it seems unnatural and ridiculous to comprise several distinct stories under one order; and if it seems so in theory, it has certainly no less the appearance in practice.

This system, however, was fortunately by no means universal; it was a more usual practice to give to each story its separate order, and this employment of different orders, or repetitions of the same order one above the other, in the several stories of a building, affords us another important feature of the style. This practice led to some other peculiarities, worthy of especial notice, amongst which may be noticed, that of abandoning all proportion of intercolumniation, and spacing the columns according to the breadth of the piers, and the apertures between them. This again led to the abandonment of insulated columns, and the substitution of engaged columns of half or three-quarter projection; the reason for which is evident, for if insulated columns had been adopted, when placed at so great a distance from each other, they would have had an exceedingly tame and meagre effect, especially when raised tier above tier. But another alteration was still requisite, for with half or three-quarter columns, the entablature was made to project so far from the face of the wall as to produce the appearance at once of heaviness and weakness, the overhanging entablature seeming to have no support between the widely separated columns. To obviate this inconsistency, the Italians fell into a still greater, by breaking the entablature over each column, and recessing it in the intercolumn. We say a greater inconsistency, for the nature and functions of the entablature are thus entirely disregarded, but, as before observed, the designs of the Italians will not bear comparison with the requirements of constructive science. This objection, however, was somewhat lessened by the introduction of pilasters in the place of columns, which, from their slight projection, allowed the entablature to be continued without break or interruption. This was so far an improvement, but it will be noticed, that all this while, the columns and other divisions of the order were losing their natural character and office, and had at last dwindled down to nothing better than aids to decoration. Thus, by their diminution in size and projection, and by their loss of constructive propriety, columns became of little significance when compared with the windows and other apertures, which were often highly decorated with architraves and cornices, and sometimes with small columns in the jambs supporting an architrave and pedimental head, which was either triangular or segmental. This method of decorating the windows was employed where each story of the edifice was arranged as a separate order; but not unfrequently the order was entirely omitted, and columns employed only as decorations to apertures, and often were dismissed altogether, the windows having an architrave dressing only, with cornice supported by ancones on either side of the architrave. These illustrate the triumph of fenestration over the combination of the two systems; and if the former do not excel in appearance, which we are somewhat inclined to think it does, it at least surpasses in consistency. We have fair specimens in London in the Reform Club and Bridgewater House, by Mr. Barry, as also of the other system in the Carlton, Conservative, and Army and Navy Club Houses, all of which, and several other excellent examples, are in close proximity to each other, and afford ample means of judging of their comparative merits.

The walls of Italian buildings are frequently formed of rustic masonry of various descriptions, and this is more generally the case with basements, and the lower or less important stories, and in such a situation gives an appearance of great strength and massiveness, where it is most required; it adds also to the apparent strength and durability of the entire edifice; not, however, without imparting at the same time a degree of heaviness. This method of decoration, if it may be so termed, is sometimes applied to columns, but it is rather a barbarous ornamentation, as is also another practice very prevalent, of leaving projecting cubical blocks surrounding the shaft of the column at regular intervals in its height. In edifices of the astylar system, the angles are often finished with quoins.

We must not forget to allude to a feature which is common to almost all Italian buildings, and that is, the boldly projecting cornice, or cornicione, as it is termed, at the summit. It is of very unusual projection, proportioned to the entire building, and often very highly enriched; it forms a noble finish or crowning, and adds considerably to the importance of the façade. Sometimes the edifice terminates with an attic or cornice with a balustrade, which again is crowned at intervals by statues or other acroteria. Columns and pilasters in this style are frequently set upon pedestals, which is an innovation upon classic art, copied from the Roman triumphal arches, in which the practice was first resorted to. Columns also are frequently fluted in a spiral direction round the shaft, which gives them an appearance of weakness; they are also twisted and crooked, which produces an effect no less disagreeable, than the construction is unscientific and barbarous. Another innovation upon ancient precedent consisted in breaking the outline of the pediment by cutting

it in the middle like a mitre; this practice was even more unsightly and unscientific than the preceding; for whereas the ancient pediment was formed for the purpose of throwing off the rain; this, on the contrary, would seem to be shaped for the very purpose of collecting and retaining it. This barbarism is frequently accompanied by another equally unauthorised and equally ugly; we allude to the practice, when the upper of two colonnades is narrower than the lower, of placing on each side of the upper story, a huge reversed console, or sort of volute, which has an exceedingly unsightly appearance. This arrangement is of common occurrence in churches, where the aisle-roofs are lower than than that of the nave, the difference of level being made up by these tasteless masses. These few last mentioned peculiarities form some of the worst features of the style; many buildings, however, are entirely free from such defects, and are of chaste and elegant design.

As we have above stated, the first attempt towards the introduction of this style was made by Arnulfo di Cambio, in his design for the duomo of Florence; but very little progress was made in this direction till the time of Brunelleschi, who may be said to be the father of the Italian style. From his time the style rapidly extended its influence throughout Italy, and was considerably varied, and in some instances improved upon, by his successors; of the life and works of the principal of them, a short account will be found in the succeeding table:—

Name of Architect.	Born.	Died.	Native of	Practised at	Erected buildings.	Wrote works.
Brunelleschi.	A. D. 1375	A. D. 1444	Florence.	Florence, Rome, and Mantua.	Dome of Cathedral, and Church of San Lorenzo, and commenced the Palace Pitti, Florence.	
Alberti.	1400		Florence.	Rome, Florence, Mantua, and Rimini.	Palazzo Rucellai, part of the church of the Annunciation, Florence; Church of St. Francis, Rimini; and St. Andrew, Mantua.	De re Ædificatoria.
Bramante bino.	1444	1514	Castel Durante, or Fermignano.	Rome.	Cloister of Convent della Pace, Cancellaria, Palazzo Giraud, part of the Vatican, commencement of St. Peter's, and the oratory of the cloister of San Pietro Montorio, Rome.	
Micheli.	1484		Verona.	Verona.	Palazzi Pompeii, Berilacqua, Canossa, Verona; and Palazzo Grimani, Venice.	
Michael Angelo, Buonarotti.	1474	1563	Florence.	Rome	St. Peter's Cathedral, finished the Farnese palace, Rome; and portions of Church of San Lorenzo, Florence.	
Sansorino.	1479	1578	Florence.	Venice.	Libreria Vecchia, Palazzi Cornaro and Delfino, La Zecca, the Public Library, and the Church of San Francesco della Vigna, Venice.	
Serlio.	1475	1552	Bologna.	Vicenza and Fontainebleau.	Theatre, Vicenza; Palace Fontainebleau.	Opere di Architettura.
Vignola	1507	1573	Vignola, Modena.	Bologna, Assisi, Perugia, Rome, &c.	Palazzo Isolani, near Bologna; Church at Massano; the Madonna degli Angeli, Assisi; St. Francesco, Perugia; Villa Giulia, Church of St. Andrea, Rome; Palace at Caprarola.	Treatise on the Five Orders.
Palladio.	1519	1580	Vicenza.	Vicenza, Venice.	Palazzi della Ragione, Tiene, Valmarana, Chieracati, Porti, Barberino, and Villa Capra, and Teatro Olimpico, Vicenza; Churches of St. Giorgio Maggiore, and Il Redemtore, Venice.	
Scamozzi.	1552	1616	Vicenza.		Finished Public Library, Venice; and the Teatro Olimpico, Vicenza; Cathedral of Salzburg, the Churches of St. Nicholo di Tolentino, and SS. Simone e Giuda, and the Procuratie Nuove, Venice; Palazzi Roberto Strozzi, Florence; and Pretorio and Trissimo, Vicenza.	Treatise on Perspective. Architettura Universale
Borromini.	1599	1667	Como.	Rome	Churches of La Sapienza, St. Agnes, and the College di Propaganda, Oratory Chiega Nuova, and the Doria Palace, Rome.	
Bernini.	1598	1680	Naples.	Rome.	Palace Barberini, Façade of the College di Propaganda, Colonnade in front of St. Peter's, and Colonnade joining the Vatican, the Church of St. Andrea à Monte Cavallo, the Palace Bracciano, &c.	

Italian architecture is usually divided into three kinds, which, with a very decided similarity in general treatment, have peculiarities sufficient to distinguish them from each other. The three classes are named after the cities in which they each prevailed, not that any one of the styles were in use at any place to the exclusion of the others, but that each style was predominant in its own locality. The cities are those of Florence, Rome, and Venice, and the classes are styled after their names—Florentine, Roman, and Venetian.

The architecture of Florence, and more especially of its palaces, is very peculiar; strong, massive, severe, and from these very qualities, grand; but at the same time gloomy and heavy, presenting the appearance of fortresses rather than the residences of merchants. Nor was this appearance a false or deceitful one, for the strength of these mansions was required for purposes of defence. The rival parties of the Guelphs and Ghibellines, and, at a later period, of the Neri and Bianchi, were the cause of ceaseless civil discord, and their quarrels kept the city in a state of continual commotion, from an early period of its history, to the time of the Medicis. It was this state of circumstances which originated the peculiar appearance of the buildings to be found in this city. Large blocks of stone were readily procurable from the quarries of Tuscany; and solidity and strength were, to some extent, demanded in residences which were not unfrequently required to answer the purpose of a stronghold. Florentine buildings excel in dignity and grandeur those of Rome and Venice, but fall far short of them in lightness and elegance; they are inferior in the refinement of detail, but surpass all others in bold and imposing masses.

Although the revival of the classic orders first took place at Florence, in the cathedral of the above city, yet the previous style, or rather many of its details, lingered there for a considerable time, and even as late as the middle of the

fifteenth century, as is evident in many of the windows, some of which have the intrados of their archivolts semicircular, while the extrados is carried up in a pointed arch; others again are composed of two lights with semicircular heads, both enclosed within a larger semicircular arch, and the lights divided by a central column. The apertures on the ground floor are usually square and unimportant, and the naked of the wall of this and the other stories most frequently rusticated, a mode of decoration very much in vogue. The façades are usually continued in an unbroken line, and there is little diversity in plan. A bold cornice runs round the summit of the edifice, which is proportioned to the entire building, although smaller cornices frequently intervene between every two stories. A very important distinction between this and the other two classes of Italian architecture, is evidenced in the absence of columns from the external façades.

The court in the interior presents often a very different aspect from that of the exterior; indeed, the external distribution scarcely ever indicates that of the interior, which generally consists of a colonnaded or arcaded quadrangle.

"The buildings of Florence," says a French author, "appear to be not the work of ordinary men; we enter them with respect, expecting to find them inhabited by beings of a nature superior to ours. Whether the eye is arrested by monuments of the age of Cosmo de Medici, or of the times which preceded or followed it, all in this imposing city carries the imprint of grandeur and majesty. Frequent revolutions obliged the chief parties to consider their personal safety along with the magnificence of their dwellings. Externally, they are examples of the skilful union of grace with simplicity and massiveness, internally models of exquisite taste. After Rome, Florence is the most interesting city to every artist."

Brunelleschi may be said to have been the founder of this style, and he was succeeded by Alberti, Raffaelle, Sanzio, Ammanati, and others; the style dating from A. D. 1400 to 1600. Some of the finest examples are the cathedral, the palaces Strozzi, Pitti, Medici, Riccardi, Vecchio, Podesta, and the churches of SS. Michele, Maddelina, Pancrazio, Lorenzo, and Spirito.

Descriptions of a few of the above edifices may not be out of place.

The Cathedral of S. Maria del Fiore, or the Duomo, as it is termed, was the first building in which the Italian features were introduced; several of the peculiarities of the old style still remaining, so as to give to the edifice a kind of transition-character between the Gothic and Italian, of which it is a mixture. The edifice was commenced, A. D. 1298, by Arnolfo, and not entirely completed by Brunelleschi, who constructed the dome. The plan is that of a Latin cross, the length measuring 520 feet, and the width across the transept 313 feet. The nave is divided into three aisles by arcades resting on piers, decorated with Corinthian pilasters, the height of the central avenue being 153 feet, and that of the aisles, properly so termed, 96½ feet. The space at the intersection of the arms of the cross is octagonal, being 140 feet in width, and the terminations of the choir and transepts are semi-octagonal, covered with semi-cupolas. Above the top of these cupolas, at the intersection of the nave and transepts, rises an octagonal drum, with a circular window on each side, and terminated at the top by a horizontal cornice from which springs the octagonal dome. Above this again is a lantern, on which rests an octangular pyramid, surmounted by a ball and cross. The drum rests on four massive piers, its height is 43 feet, and the thickness of its wall 16 feet. The dome is double, consisting of two shells one within the other, with an interval of 5 feet between; the thickness of the lower shell being 4 feet 3 inches at the lower extremity, and 1.0 foot at the vertex; and of the inner one, 5 feet 6 inches at bottom, and 2 feet 1 inch at vertex. The span of the dome is 140 feet, the radius of internal curvature, 120 feet; height from drum to lantern, 116 feet; from ground to cupola, 280 feet; height of lantern, 45 feet; diameter, 24 feet.

The arcade in the nave consists of pointed arches, each segment being described with a radius equal to two-thirds of the span. From the top of the piers, or rather of the pilasters which adorn them, rises a second order, to support the ribs of a pointed vault. The aisle-windows are of two lights, divided by a central column, and having trefoil heads to each light, both of which are included under a larger pointed arch; on the exterior they are crowned by a rectilinear pediment, with a pinnacle at either end. The upper windows are circular. The external wall is almost entirely encased in coloured marbles, and is ornamented with pilasters, which at the eastern extremity are connected by semicircular arches.

Attached to the cathedral is a separate campanile, erected by Giotto and Taddeo Gaddi, A.D., 1334, which consists of five stories, ornamented on the exterior with pilasters, like the cathedral. The three lowermost stories have narrow rectangular windows, the fourth two tiers of pointed windows, of two lights each, divided by a twisted pillar, and having trefoil heads, and the uppermost one wide pointed window of three lights. At the summit is a gallery supported on brackets.

The Pitti palace was designed and partially erected by Brunelleschi, at the close of the fourteenth century. The main body or central portion of the building, is in plan a parallelogram, with a wing projecting at right angles at each extremity; behind the centre is a small cortile. In elevation, the edifice consists of three stories of equal height, each story being somewhat less in frontage than the one below it, so as to give to the whole the appearance of a pyramid, which appearance would have been increased, had the original design been carried out, in which a fourth story was contemplated. Each of the stories is of rustic masonry, and crowned by a cornice supporting a gallery with balustrade in front. The windows are placed one above another, and number alike, except in the lower story, where there is only one window under each alternate one above. They are semicircular-headed apertures, and have the voussoirs grooved at the joints. The elevations of the cortile consist of three orders, one to each story; the lowermost of which is Tuscan, with shafts fluted horizontally. The second order is Ionic, with square blocks ranged at intervals up the shaft, and between the columns are semicircular-headed recesses, containing windows, which have architraves and pilasters on the jambs, and are crowned by pediments; underneath each window is a projecting table, supported by two corbels placed under the architrave. The uppermost order is Corinthian, also with square blocks on the shafts, and between the columns are recesses with horizontal lintels, formed by voussoirs; within which again is another semicircular-headed recess, and windows crowned by a curvilinear pediment.

The Palazzo Strozzi is of rusticated masonry throughout the entire façade, in horizontal and vertical channels. The building consists of three stories; in the centre of the lowest is a doorway, with semicircular head flanked on each side by three windows having square heads. The windows in the upper story consist of two lights separated by a column, and having half-columns in the jambs. Both the lights have semicircular heads, and are

included under a common semicircular arch, the spandrils of which are filled up with pateræ. Each story is separated from the adjoining one by a frieze of dentils, the entire building being crowned with a plain frieze and boldly projecting cornice, in which both dentils and modilions are employed.

The Richardi palace consists of three stories, as does the Strozzi palace, which it resembles also in many other features. The lowest story, however, is somewhat peculiar, being formed of uncoursed masonry, with some blocks projecting forward beyond the others; as in the previous example, the doorway is semicircular in the head. The second story is rusticated, and contains seventeen windows in close proximity to each other; they are of two lights, with a column in the centre, and have semicircular heads, which enclose the heads of the two lights, also semicircular. Above these windows is a large surface of naked wall, above which is a dentil band, separating this story from that above. The third story is of plain ashlar, and contains windows the same in number and description as those of the second story; the whole is crowned by a bold cornice.

The church of San Lorenzo, by Brunelleschi, is in plan a Latin cross, the length of which is considerable when compared with the width; the height of the building follows the same proportions. The body of the church is divided into a central nave with two aisles, by means of an arcade; the arches of which rest upon Corinthian columns, carrying isolated entablatures, from which the arches spring. At the intersection of the nave and transept, the building is covered by a spherical dome, which stops short ere it meets at the summit, the void so formed being covered by a hemisphere of smaller diameter; this answers to the lantern more usually applied in such positions.

"The church of Santo Spirito is a beautiful example by Brunelleschi. All the fronts are complete except the principal one, and it is certainly the finest of Brunelleschi's designs; though subsequent to the architect's death, as the works were then unfinished, they were carried on with some departure from the original design. These alterations, though not affecting the general conception, have justly excited the anger of Vasari against those who fancy themselves better qualified than artists. Oh that Vasari were alive now! The plan is a Latin cross, with aisles carried round the transepts of the choir. The intersection is surmounted by a dome ornamented with leaf-work, and rising from a low tholobate, pierced with circular openings. The clere-story and aisles have circular-headed windows. The wall being of great thickness, there is sufficient space for large niches, which occupy each intercolumn, and the wall of the lower clere-story, or that to the aisle is above the inside to the lower wall, and has circular windows similar to those of the tholobate. Thus there were three distinct levels of roof besides the dome. The interior has Corinthian columns, each supporting an entablature, from which spring semicircular arches. At the extremities of the choir and transepts there are four windows, instead of an odd number. The high altar beneath the dome is surmounted by a magnificent canopy. There is an internal dome with a lantern beneath those of the exterior. It is panelled, and perforated by the windows of the tholobate. In this church we remark the most perfect harmony of lines. Character is given to the building by the constant use of circular forms, whilst too great sameness is prevented by the occasional use of horizontals. The sacristy attached to this church, and the second cloister, are both fine works."

The edifices of Rome are of a very different character to those of Florence; they have lost the massive appearance of the latter, and assumed an air of lightness and elegance. This style forms the connecting link between the Florentine and the Venetian; for while, on the one hand, it is much less heavy and severe than the former, it is not so gay and lightsome as the latter. Columns are of frequent introduction in the façades, in which, also, the entrance becomes an important feature. The interior courts are mostly surrounded by arcades, and from them a grand staircase of imposing dimensions leads to the principal apartments. The churches consist of nave and aisles, separated by arcades, the latter being flanked by chapels. The transepts are not extended far beyond the nave, and the intersection is covered mostly by a dome. Apsides are common. The façades are generally of an inferior description, often plain; and when decorated, it is without taste; they are often only masks, having no relation to the internal distribution of the edifice. Bramante was the founder of this style; and the principal examples are St. Peter's cathedral and the Farnese palace, which we proceed to describe. Of the former, which is a subject of general interest, we shall take this opportunity of giving a full description.

The plan of St. Peter's is that of a Latin cross, with a narthex, or porch, at the west end, extending in width beyond the general line of the building. Internally, the breadth of the church is divided into three portions, central nave and aisles on either side, by means of an arcade, supported on massive piers, four of which, at the angles formed by the intersection of the nave and transept, are more massive than the rest, and serve to support the central dome. There are four arches on each side of the nave, and one in the choir, all springing from piers which are ornamented with pilasters. A chapel is formed at the extremity of each aisle, where they meet the transept, which is rectangular in plan, projecting beyond the general line of building on the exterior, and covered with a spheroidal dome. At the western extremity of the nave is a porch, as above noticed, extending in frontage from north to south beyond the main line of the building, and projecting from the extremity of the nave as much as 50 feet; this porch is separated from the nave by a wall containing five doorways, to agree with the number of doors in the outer wall of the porch itself, which forms the grand façade and entrance. The elevation of this façade is adorned with half-columns and pilasters, ten in number; leaving nine intercolumnar spaces in the whole façade; the columns are surmounted by an entablature, the height to the top of which is 125 feet, and the four central columns are included under a pediment rising above the entablature, which in consequence is broken above these columns as it is also above every column beyond the pediment. This order contains two stories in height, the lower one being occupied by the entrances, and the upper by windows. In the central compartment of the lower story is the principal doorway, with horizontal head, and in the nearest compartments on either side a smaller doorway with semicircular head, on either side of which again is one more similar to the first. In each of the extreme intercolumns which project beyond the main building is a magnificent doorway with semicircular head, and similar ones on the two other sides of each of those projections which are not contiguous to the church. In the upper story of each of the intercolumns is a window, with a segmental or triangular pediment, the two forms alternating with each other. Above the entablature is another story or attic, and above this again a balustrade.

From the four great piers at the intersection of the nave and transept, spring four large semicircular arches which support a drum or cylindrical wall 70 feet high, and perforated at intervals by windows. The windows are rectangular, surmounted alternately by triangular and segmental pedi

ments; and between every two are a pair of coupled Corinthian columns, supporting an entablature projecting over each column. Above the entablature the wall rises 20 feet, and upon the top of this, springs the magnificent dome: it is a double dome consisting of an external and internal shell at a short distance from each other, the extreme diameter of the outer one measuring 189 feet, and that of the other on the inside, 138 feet. Both domes are of the spheroidal shape, but the inner is flatter than the outer one, the height of the former being 77 feet, while that of the latter is 100 feet; they are connected together by sixteen vertical ribs of masonry. Above the cupola is a lantern 40 feet in height, and above that a small spire supporting a ball and cross. There are three tiers of windows in the dome.

From the front of the church, and commencing at the extremities of the porch, project two corridors, one on each side, in such a manner as to approach nearer and nearer to each other as they recede from the façade of the building, and enclosing a space of ground or area in the form of a trapezoid, the length of which from east to west measures 400 feet. From the western extremity of each of these corridors, is carried a semicircular colonnade, which is surmounted by an entablature and balustrade, crowned at regular intervals by statues. The area thus enclosed is 650 feet long from north to south, and 500 feet from east to west; in its centre is a large Egyptian obelisk of black marble, and on each side of it a large fountain. The trapezoidal area contains the steps to the cathedral.

The original design for this cathedral was furnished by Bramante, but was altered by almost every architect employed upon the building, so that he cannot lay claim to the design of it as executed. Bramante commenced the erection, but did not proceed far with the work, the body of the church being erected by Peruzzi and San Gallo; the dome by Michael Angelo and Fontana; the nave and west façade by Carlo Maderno; and the colonnades by Bernini. The plan was originally designed as a Latin cross, which was changed into a Greek cross by Michael Angelo, and again into the Latin form by Carlo Maderno.

The following dimensions of the cathedral and its several parts may be found useful, especially in the comparison of this and our cathedral of St. Paul, the dimensions of which are given in a parallel column.

The Plan.—Length and Breadth.

	St. Peter's. Ft.	St. Paul's. Ft.
The whole length of the church and porch	729	500
The breadth within the doors of the porticos	510	250
The breadth of the front with the turrets	364	180
The breadth of the front without the turrets	318	110
The breadth of the church and three divisions of the nave	255	130
The breadth of the church and widest chapels	364	180
The length of the porch within	218	50
The breadth of the porch within	40	20
The length of the plateau at the upper steps	291	100
The breadth of the nave at the door	67	40
The breadth of the nave at the third pillar and tribune	73	40
The breadth of the side aisles	29	17
The distance between the pillars of the nave	44	25
The breadth of the same double pillars at St. Peter's	29	—
The breadth of the same single pillars at St. Paul's	—	10
The two right sides of the great pilasters of the cupola	65.7½	25.35
The distance between the same pilasters	72	40
The outward diameter of the cupola	189	145
The inward diameter of the same	138	100
The breadth of the square by the cupola	43	—
The length to the same	328	—
From the door within to the cupola	313	190
From the cupola to the end of the tribune	167	170
The breadth of each of the turrets	77	35
The outward diameter of the lantern	36	18
The whole space upon which one pillar stands	5,906	875
The whole space upon which all the pillars stand	23,625	7000

The Height.

From the ground without to the top of the cross	437½	370
The turrets as they were at St. Peter's and are at St. Paul's	289½	222
To the top of the highest statues on the front	175	135
The first pillars of the Corinthian order	74	33
The breadth of the same	9	4
Their bases and pedestals	19	13
Their capitals	10	5
The architrave, frieze, and cornice	19	10
The Composite pillars at St. Paul's, and Tuscan at St. Peter's	25½	25
The ornaments of the same pillars above and below	14½	16
The triangle of the mezzo relievo with its cornice	22½	18
Wide	92	74
The bases of the cupola to the pedestals of the pillars	36½	38
The pillars of the cupola	32	28
Their bases and their pedestals	4	5
Their capitals, architrave, frieze, and cornice	12	12
From the cornice to the outward slope of the cupola	25½	40
The lantern from the cupola to the ball	63	50
The ball, in diameter	9	6
The cross, with its ornaments below	14	6
The statues upon the front, with their pedestals	25½	15
The outward slope of the cupola	89	50
Cupola and lantern, from the cornice of the front to the top of the cross	280	240
The height of the niches in front	20	14
Wide	9	5
The first windows in front	20	13
Wide	10	7

Mr. Gwilt has prepared a table of areas of the two edifices, as also of that of the Duomo, Florence; and as this table contains likewise the area occupied by piers and other means of support, it will give an idea of the comparative merits of the buildings as regards construction, and when taken in connection with the comparative sectional areas,

will give a just ratio between the size or capacity of the building, and the quantity of material employed in its construction.

	St. Peter's.	St. Paul's.	St. Mary, Florence.
	Ft.	Ft.	Ft.
Area on plan	227,069	. . 84,025	. . 84,802
Do. of points of support	59,308	. . 14,311	. . 17,030
Ratio of areas . . .	1.0261 . .	1:0170 . .	1:0201
Sectional area at transepts	8,325:10000 . .	6,865:10000 . .	8,855:10000

We shall have to speak more particularly about St. Paul's presently, but must now return to examples to be found at Rome.

The great Farnese palace is probably one of the finest specimens of Italian palatial architecture in existence, and covers an area of 256 feet, by 185 feet, the height of the building measuring 177 feet. The material of the walls is brick, with the exception of the dressings, which are of Travertine stone. The edifice is three stories in height, each of which contains a range of thirteen windows, with the exception of the first, where the place of one is occupied by a doorway; those on the first story are of a rectangular form, with architrave, and horizontal cornice, supported by ancones, or corbels on either side of the window. The doorway is semicircular-headed, with prominent voussoirs. The windows in the next story are of a more ornamental character, being still of the rectangular form, but having pediments alternately triangular and segmental; the jambs, also, are decorated with columns. In the uppermost story, the windows have semicircular heads, with columns and triangular pediments. The stories are separated by impost cornices, and the entire building crowned by a boldly projecting cornice. In the interior quadrangle, the building surrounds a court 88 feet square, and presents a very different appearance to the exterior, being divided vertically into arcades. The lower arcade is of the Doric order, and is supported on piers whose sides are adorned with Doric columns, and which sustains an entablature enriched with triglyphs, &c. The upper arcade is of the Ionic order.

The Palazzo Giraud at Rome is by Bramante, and consists of a range of building enclosing a quadrangle 89 feet square, the external measurements being 249 feet by 190 feet. The front elevation contains three stories, all of which are rusticated, the lowermost by both horizontal and vertical grooves, but the upper by horizontal grooves only. In the centre is a semicircular-headed door, with horizontal cornice, and on each side of it three square windows. In the second story, the piers between the windows are ornamented with coupled pilasters, similar to those of the Corinthian order, standing on high plinths, which again rest on a podium extending all along the building, but broken under the pilasters. The pilasters support a simple entablature, and between them are seven semicircular-headed windows, with horizontal cornices, the archivolts resting on pilasters, and the spandrels filled with sculpture. Above the piers of the second story, the third story have coupled Corinthian pilasters, arranged in a similar manner on plinths and podium. Between these are two tiers of windows, the lower having rectangular, and the upper semicircular heads. Above this order is the entablature proportioned to the building, the frieze of which is occupied by blocks to support the cornice. The roof has sloping sides, and is covered by hollow tiles.

In one of the shorter sides of the building is the vestibule, which is 47 feet long, by 34 feet wide, and is divided longitudinally into three portions by two rows of columns. This gives entrance to the principal court, which is surrounded by an arcade resting on piers, ornamented with half-columns, and roofed with a groined ceiling. Opposite the entrance is a passage, the sides of which are ornamented with pilasters and niches, and which leads to a smaller court in the rear.

The Venetian style is characterized by its pre-eminent lightness and elegance, and more especially by the frequent and almost universal employment of pilasters and arcades; it bears altogether a more lively and decorative character than either of the preceding. Another feature having a similar tendency is shown in the close proximity of the windows, and the large proportion of the elevation occupied by apertures. San Michaeli, or Sansovino, may be said to have been the founder of this school, and they were followed by Palladio, Scamozzi, &c. Good examples are, the library of St. Mark, Venice, the Pompeii palace, Verona, and the chapel of St. Bernardino.

The library of St. Mark, Venice, is by Sansovino, and consists of two stories, each composed of one order, the lower one Doric, and the upper Ionic. The lower story is raised three steps above the piazza, and consists of a portico of twenty-one arches, at the back of which is a range of similar arches used as shops, and opposite the central arch is a magnificent staircase leading to the library. The piers of this story are ornamented in front by pilasters of the Doric order extending to the top of the arches, and carrying a noble entablature enriched with triglyphs, and above them with a fine cornice, with dentil-band underneath. The archivolts rest on a moulded cap or impost, and have carved key-stones which finish under the entablature. Above this is an Ionic order carried upon pedestals, ranging with which, and underneath the windows, is a balustrade, flanked by other smaller pedestals, upon which stand small Ionic columns placed in the jambs to support the archivolt, the windows having semicircular heads. As below, the order extends to the top of the arches, which have ornamented key-stones, and rest on impost mouldings; the spandrels between the archivolt and the pilasters being filled up with sculpture. The entablature to this order is very lofty, and the frieze highly decorated with sculpture; the cornice is bold, and highly enriched, being supported by modillions, and having a dentil-band underneath. The cornice is crowned by a balustrade, on every alternate pier of which is placed a statue, and at the angles of the building a pyramidal acroteral ornament.

In the same piazza is the Procuratie Vecchie, also by Sansovino. This building consists of three stories, the lowermost of which has an arcade supported on piers, and the upper ones a similar arrangement on columns, the arches of these stories, however, being so much smaller than those below, as to be admitted in pairs above the single ones on the ground-floor. The stories are divided by plain podia, and the whole crowned by an entablature, with a frieze perforated at intervals with circular apertures.

The Pompeii palace, by Michaeli, consists of two stories, the lower one of which is rusticated throughout, the apertures, with door and window, having semicircular heads, without architrave or other decoration; the doorway is in the centre, having three windows on either side. Above each of the apertures is a balustrade, and above these are the upper windows, which are of similar shape, but the piers between them are decorated with single three-quarter columns of the Doric order, which support an unbroken entablature over the windows.

Amongst the buildings of this class, we have to notice those of an architect, whose works may be said to comprise a new style, and which, for this reason, have been designated the Palladian style. Many opinions have existed, and do still exist, respecting the merit of Palladio's works, and the

school which they gave rise to, some writers extolling them above all others of the Italian style, and others decrying them with equal zeal; for ourselves, we must confess that we are no great admirers of his school.

In Palladio's designs, the ground stories are generally composed of arcades of not very ornamental design, serving as basements to the principal stories above, which are decorated with an engaged order, and most frequently with a pediment in the centre of the building above the cornice, though sometimes, when a pediment is introduced, the cornice is discontinued beneath it. His buildings frequently have vestibules consisting of three arches or rectangular openings in front. The arches of his arcades are usually of the semicircular form, but sometimes the space between the piers is subdivided into three portions by two lesser piers, the central compartment only being arched over. This form is sometimes carried out in his windows, which, however, are usually rectangular; sometimes also a semicircular shape is adopted, divided into three parts by vertical mullions.

In his churches he follows the Basilican form faced with a portico consisting of an order with entablature reaching to the height of the building, and covered by a pediment rising with the nave-roof, those of the aisles having each a kind of half-pediment to agree with the slope; so that the central pediment has the appearance of having been placed in the centre of another so as to divide it equally into two parts. Amongst Palladio's other works, those of the church of the Redeemer, and the Olympic Theatre at Vicenza, stand conspicuous.

The form of this latter building is semi-elliptical, round which the seats are extended in front of the proscenium. The entire width of the building is 109 feet, that of the proscenium 80 feet, and its depth 21½ feet. The front of the scena is composed of two tiers of Corinthian columns on pedestals, the lower tier of which is detached with pilasters behind, and the latter are half-columns attached to the walls. Between the columns stand niches with rectangular and circular pediments resting on fluted Corinthian pilasters, and above the upper tier is an attic broken by piers, the spaces between which are filled with sculpture. Three doors in the scena give admission to five passages, the sides of which are adorned with representations in relief on wood of a variety of buildings seen in perspective. The upper tier of seats is surrounded by a row of Corinthian columns, supporting an entablature, and this again surmounted by a balustrade with statues.

The church of the Redeemer at Venice was built by this architect. The form would be that of a Latin cross, were it not that the nave is flanked on either side by three chapels open to the body of the church, ranging the entire length of the nave, and receding from it to the same depth as the transepts. The division between them and the nave is effected by an arcade of semicircular arches springing from entablatures over Corinthian pilasters, which flank the piers of the nave. These piers are faced towards the nave by half-columns coupled, and extending to such a height as to carry an entablature over the arcade; above which on each side is a clere-story pierced with three semicircular windows, divided into three by vertical mullions. The choir is surrounded by isolated columns, and its extremity, as also those of the transept, is apsidal. At the intersection a cylindrical drum is supported on four large arches, and is surmounted by a cupola or dome.

The church is considerably elevated above the ground, and is approached on the exterior by a flight of steps extending the breadth of the nave, and fronting the portico, which consists of two three-quarter columns and two pilasters, covered by a pediment. On each side of this, a wing projects in the line of façade, adorned with Corinthian pilasters of less height than those of the portico, and continued round the sides of the building. The door under the portico is semicircular-headed, ornamented with half-columns, entablature, and pediment. The roofs of the aisles lean to, and in the façade present the appearance of a second pediment broken in the middle for the insertion of the portico.

After the death of Palladio, Italian architecture began to decline, under the auspices of Borromini. This architect introduced many innovations, and in his desire to produce novelties, had little care for elegance or simplicity; striving to surpass his rivals and predecessors in variety and originality, he laid aside all the common rules and restrictions, and gave form and substance to all the extravagant vagaries of his imagination. In his designs, straight lines are the exception, curvature and irregularity their ruling features. Curves, both convex and concave, appear in plan and elevation, wherever it was possible to introduce them, and that without any regard to construction; his designs are the result of an inventive and pregnant, but also a reckless and uncultivated, fancy.

The church della Sapienza, by this architect, is of a polygonal plan, of which the sides are alternately concave and convex; the exterior of the cupola, which is surrounded above by a balustrade, is of a similar plan, the convex parts being formed into steps, interrupted by buttresses. But the lantern is still more whimsical, having its vase in a zig-zag form, on which is erected a spiral staircase, sustaining a crown of metal, with a ball and cross at the top. His most extraordinary work is the church of San Carlino alle Quatro Fontaine, which abounds in his eccentricities, as does also the oratory of the Fathers della Chiesa Nuova. Here we have disorderly mixtures of all kinds of lines, straight and circular, convex, concave, and twisted; undulating coronæ which retain the rain, delicate mouldings under great weights, and strong supports without anything to sustain; breaks only in the architrave of the entablature; prominences, contortions, and every kind of absurdity. Of all his buildings, the church of St. Agnes in the Piazza Navona, is most free from his usual abuses; the façade of this, however, is in plan a curve of contrary flexure.

Bernini's buildings, though not of so bizarre a character as Borromini's, are not equal to those of his predecessors; his principal works are the colonnade in front of St. Peter's, the principal façade and staircase of the palace Berberini, the Curia Innocenziana, and some few others. Of the first of these works, a description has already been given, we pass on therefore to the second.

The palace Berberini consists of a central portion and two wings, which project at right angles to the front. In the lowest story of the central compartments, are two parallel rows of arches resting on piers, forming a vestibule, which has a groined roof. The building consists of three stories, the lower one being ornamented with a Doric order, and the upper with Corinthian columns, between which are semicircular arches springing from imposts. Each of the wings has three tiers of rectangular windows placed in recesses, which are formed by narrow projections of the wall after the manner of pilasters. Attached to this building is a Belvedere turret, with windows in each side, and having pilasters on the exterior.

The best period of Italian architecture was now over, and there are scarcely any buildings erected after this time which require comment; we shall therefore pass on to a considera tion of this style as practised in England.

During the time of Palladio, Italian architecture began to

be copied successfully in various parts of the Continent; and Palladio's method had become very generally popular. A mixture of Italian and Gothic architecture had been in vogue since the time of Elizabeth, after whose name the style procured the title of Elizabethan; the pure Italian, however, did not make its appearance here till the reign of James I., and Inigo Jones was the first architect to introduce it. In the early part of his practice, this architect had followed the mixed style, but on his return from a journey to Italy, he brought back with him the manner of the Palladian school, in which his principal works were, the portico of Old St. Paul's, Whitehall Palace, York-stairs, and the church of St. Paul, Covent Garden.

The first building of unmixed Italian architecture erected in England, was that of Whitehall, by Inigo Jones. This edifice was commenced during the reign of James I., A.D. 1619, but was never completed according to the original design, which contemplated the erection of an immense range of building containing seven courts, extending in one direction from the park to the river, the façade towards which would have measured 720 feet, and that towards Charing Cross, no less than 1152 feet. Only a small portion of this magnificent design was carried into execution, and this was the banqueting hall, which was completed in two years. This portion is 115 feet in length, and from its appearance we may form some idea of what the entire building would have been. The hall consists of three stories, of which the lower one is a plain rusticated basement, with simple rectangular apertures, without architrave or other decoration; the upper ones consisting of two complete orders, the lower of which is Ionic, and the upper Corinthian. Each story contains seven windows, with a column or pilaster between every two, and coupled pilasters at the angles of the building, thus making up ten columns in each story. The windows are all rectangular, and surrounded with architraves, above which are cornices supported on ancones; the lower tier, however, differs from the upper in having pediments above the cornice alternately triangular and segmental; this tier is also furnished with a balustrade which is wanting in the upper story. Both orders are surmounted by a complete entablature, which is broken over each column; the walls throughout are rusticated, and the building finished at the summit by a balustrade.

Jones's next work was the new portico to the then St. Paul's, but of this of course no remains are left. St. Paul's, Covent Garden, was another work which exhibits a chaste example of the Tuscan order; it was partially destroyed by fire in 1795, but has been restored in its original character. A beautiful, though small example of Jones's taste is exhibited in York-stairs, leading down to the river from the west end of the Strand. It consists of three arches, of which the central one is the largest, and the spaces between them are decorated with four half columns, supporting an entablature which is broken over the capitals; this again is surmounted by a segmental pediment, the tympanum of which is somewhat decorated with sculpture. The Strand front differs from that towards the river, in substituting pilasters in the place of half columns.

The great fire of 1666 gave an opportunity to the newly adopted style of architecture, which in all probability it would not otherwise have obtained; nor was it a light advantage in its favour, that it secured the services of Sir Christopher Wren; who, however we may find fault with some of his works, was undoubtedly a man of unusual attainments in his profession, and of unwonted energy and perseverance. As a proof of this assertion, we need do no more than point to the multitude of buildings erected under his superintendence. Of his twenty-five London churches, his palaces, and other public and private buildings, we can here say but little; but will endeavour to give a full account of his chef-d'œuvre, the Cathedral of St. Paul, forasmuch as it furnishes us at once with a specimen of Wren's skill, and with our most magnificent example of Italian architecture, as applied to sacred purposes. We shall commence by giving a cursory glance at the history of the structures which anciently occupied the same site.

It has been thought that, during the residence of the Romans in Britain, a temple, dedicated to Diana, had occupied the situation on which the present edifice is erected; and this opinion is said to have been confirmed by the digging up, at different times, horns and skulls of animals supposed to have been sacrificed; but Sir Christopher Wren, who found no such indications in all his researches, in the extensive excavations which he made for the foundations, gives very little credit to the common tradition. However this may be, it appears that one of the earliest Christian churches in England was erected upon this site, about the year 610, by king Ethelbert, who had been converted to Christianity by St. Augustine.

Erkenwald, the fourth bishop of London, who died in 685, expended large sums upon this church; but whether for additions, or to complete Ethelbert's plan, is not ascertained. The church was accidentally consumed by fire in the year 961, but was rebuilt immediately. In 1087, it was again destroyed by a conflagration, which also laid waste the greater part of the metropolis. At this time Maurice, or Mauritius, bishop of London, conceived the vast design of erecting the magnificent edifice which preceded the present cathedral; but the undertaking was so extensive, that neither Maurice nor his successor, De Belmeis, lived to complete it. The succeeding bishops, Gilbertus Universalis, and Robertus de Sigillo, are not known to have done anything towards the finishing of the building, till the second De Belmeis, who, following his uncle's example, contributed largely towards the work. In 1135, the edifice was again exposed to the injuries of fire, which consumed all that was combustible. The enterprise of that age, however, was not to be repressed even by such repeated disasters; for, in 1221, the central tower was finished; and, in 1229, bishop Niger undertook to rebuild the choir in a new style of architecture, and enlarged dimensions: this was completed in 1240.

The cathedral was farther enlarged by the addition of the Lady Chapel, eastward of the choir: these new works, as they are called in the records of the church, were begun in 1256, and finished about 1312; in which year we find a contract for paving this additional building with marble, at fivepence per foot.

In 1315, a great part of the timber spire being decayed, it was rebuilt, and a new cross erected at the top. In the same year, an exact measurement of the building was taken, by which the length was found to be 690 feet, the breadth 130 feet; the height of the nave, from the floor to the top of the vaulting, 102 feet, and the height of the choir 88 feet. The altitude of the tower, from the level of the ground, was 260 feet, and of the spire 274 feet; and yet, according to Dugdale, who gives these dimensions, the total height did not exceed 520 feet; this difference may be accounted for, by supposing the height of the tower to have been taken to the top of the battlements, or pinnacles, and that of the spire, to have been reckoned from its base.

This lofty spire was fired by lightning in 1444; and in 1561 the steeple suffered by a similar catastrophe; but a subscription was set on foot by Queen Elizabeth, and the damages were repaired. In the reign of James I. the church had become very ruinous throughout, owing, perhaps, to some

defect in the original construction; and though large sums of money were collected, and materials provided for the reparation, it remained in the same state till the preferment of the celebrated Laud to the see of London. This prelate exerted himself zealously and successfully in favour of the neglected building, and a general subscription, supported in a munificent manner by king Charles I. was soon collected, to the amount of £101,330 4s. 8d. Having thus provided the necessary means for an entire restoration of the church, Inigo Jones was appointed to superintend the undertaking. The repairs were begun in 1633, and, in the course of nine years, a magnificent portico was erected at the west end; the whole exterior of the body of the church was new cased with stone, the roof and leaden covering were completed, and the vaulting, which was much dilapidated, and stood in need of repair, was well centred, and supported with some hundreds of tall masts.

During the time of the commonwealth, the building became exceedingly ruinous, and great part of the church was converted into stables and barracks; the choir, however, was still used for public worship.

Under the reign of Charles II. the regular government of the church being re-established, the dean and chapter proceeded immediately to remove the encroachments, and to restore the stalls and other appendages of cathedral worship; but their revenues not affording the means for a general reparation, another subscription was opened, and the repairs were commenced in 1663. Sir John Denham, the surveyor-general, had the superintendence of the works.

Dr. Wren, afterwards Sir Christopher, (as appears from the *Parentalia*) was employed to make a survey of the building, the result of which is given in an elaborate report, contained in that work. In this paper, the architect, after remarking on the general bad construction of the body of the church, and recommending a new and massy casing of stone, pronounces a final condemnation upon the tower, which, together with adjacent parts, he represents as "such a heap of deformities, that no judicious architect would think it corrigible by any expense that could be laid out upon new dressing it; but that it would still remain unworthy of the work, infirm and tottering." He therefore proposed a bold alteration of the primitive form, by cutting off the inner corners of the cross to reduce the middle part to a spacious cupola, or hemispherical roof, and upon this cupola, for the outward ornament, a lantern with a spring top, to rise proportionally; but not to the unnecessary height of the former spire. This proposal does not appear to have been much approved of by his employers, and the public opinion was expressed strongly for retaining the tower in its ancient form. The great fire of London, in 1666, at length decided the question, and this unfortunate building again became a prey to the flames, which consumed the roof; and by precipitating the vaulting, weakened, cracked, and ruined the walls and piers in such a manner, that they were judged incapable of repair. Still some years of irresolution elapsed before it was finally determined to erect a new cathedral.

Such was the fate of this venerable edifice; and, like many other monuments, it might have passed into oblivion, had not the meritorious antiquary, Dugdale, with the assistance of Hollar, preserved, in his *History of St. Paul's*, some considerable memorials of its form and decorations.

The ancient cathedral of St. Paul's must always be regarded as one of the great works of the architecture of the middle ages: in magnitude of dimension it far surpassed every other religious edifice of this country; and it is represented by historians as equally pre-eminent in magnificence and splendour of ornament.

The general form of the plan was a simple cross, with a very long choir, and a transept rather short in proportion to the extreme length of the building. The body of the church was in the Norman style of architecture; huge clustered pillars on each side divided the nave from the aisles, and supported large semicircular arches: immediately above these extended an open gallery, with arcades of the same form and width as those below, but of a much shorter proportion. From this level a different style of building prevailed, for the windows above the gallery were pointed. The vaulting, which covered the nave, was also of the pointed form, of the simplest groined construction, with soffits and diagonal ribs only, similar to Salisbury cathedral and the transept of Westminster abbey. Slender circular shafts, placed against the centre of each pier, rose from the pavement without any interruption of mouldings, and received the springing of the arches: the transept was in the style of the nave. Hence, we may conjecture that the original work of Maurice and De Belmeis comprehended the body of the church as high as the gallery; the vaulting being, undoubtedly, part of these works, which, in the preceding historical sketch, are mentioned as completed in 1221; and it thus became one of the earliest examples of the use of pointed arches in this country.

Sir Christopher Wren was of opinion, that this Norman building had been erected upon the remaining foundations of the more ancient Saxon church, for these he found to be composed of Kentish rubble-stone, cemented with mortar of extreme hardness, and both much superior to the materials used in the superstructure.

At the intersection of the nave with the transept, four massy pillars supported the tower; and, from this part, a broad flight of steps led to the choir, which was enclosed by a magnificent screen, elaborately adorned with niches and statues. The choir, which was a grand specimen of the architecture of Henry VIII.'s time, was completely in the pointed style, with a vault of a more complicated structure than that of the nave, each severy being composed of five ribs. The Lady Chapel, at the end of the choir, was a continuation of the building in the same form and style, and terminated, at the eastern extremity, by a rose window of extraordinary size and magnificence. A spacious, lofty crypt, extending beneath the eastern part of the cathedral, was appropriated to religious rites, under the designation of the church of St. Faith, and the chapel of Jesus. Three ranges of massy piers, enveloped by slender cylindrical shafts, divided the area into four equal aisles, and supported a high-pitched vault of the simplest groined construction. The exterior of the building presented a curious medley of the styles of different ages. At the western front, Inigo Jones had erected a portico of the Corinthian order, thus displaying a signal example of that bigotry in taste, which, only admitting of one mode of beauty, is insensible to the superior claims of order and congruity. This portico was, however, singly considered, a grand and beautiful composition, and not inferior to anything of the kind produced in modern times. Fourteen columns, each rising to the lofty height of 46 feet, were so disposed, that eight, with two pilasters placed in front and three in each flank, formed a square peristyle, and supported an entablature and balustrade, crowned with statues of the kings, the predecessors of Charles I. who claimed the honour of this fabric. Had the whole front been accommodated to Roman architecture, it might have deserved praise as a detached composition; but, though cased with rustic work, and decorated with regular cornices, the pediment retained the original Gothic character in its equilateral proportions, and it was flanked by barbarous obelisks and ill-designed turrets. A representation of this curious elevation

is given in the works of Inigo Jones, edited by Kent. The great restorer of Roman architecture in this country, was, doubtless, pleased with having an opportunity of triumphing over the Gothic style of building, in one of its strong holds; and it must be allowed, that he only followed the example of the architects of the middle ages themselves, who have generally shown as little moderation and respect for the works of their predecessors; since we everywhere find the styles of different eras engrafted upon each other, in the most crude and undisguised contrast.

It appears that the whole body of the church had been cased and reformed in the same manner, which had obliterated every detail of antiquity, leaving only the general forms and proportions. The buttresses were converted into regular piers, and a complete cornice crowned the whole. Some of the windows were without ornament, while others were decorated in a heavy Italian manner, with architrave dressings, brackets, and cherubic heads. The transepts presented fronts of the same incongruous style as the western elevation, and without any of its beauties. At the centre of the cross, the great tower rose aloft in pre-eminent grandeur: this was in the simple style of the early Pointed architecture. In each side three remarkably pointed windows, and the same number above, but of a shorter proportion, gave an original character to the tower, with an air of great lightness and beauty. This was the foundation of an immense spire, of which, however, there are no accurate representations; for though Dugdale gives a view of the church in its entire state, yet this could not have been taken by him from personal inspection, neither does he mention any authority; and we may observe, that the style of the spire there exhibited is evidently not authentic. At each angle enormous arched buttresses, the irregular additions of various repairs, had been erected to secure the declining tower. The rest of the building, eastward of the transept, remained in its original form, a fabric of pointed arches and flying buttresses. In the east front, the most remarkable object was the rose window, which constituted the principal ornament of the Lady Chapel.

Like other ancient religious edifices, this cathedral had numerous dependencies; some of which were, the chapter-house, an octagonal building, of a rich and elegant pointed style, and surrounded by a cloister, two stories in height, of great beauty; the *clocher*, or bell-tower, standing at the east end of the church-yard, a very ancient building, to which had been added, about the time of Henry III., a spire of timber and lead; it contained four large bells, which, with the spire and an image of St. Paul, having been staked at hazard by Henry VIII., were won and taken down by Sir Miles Partridge.

It being at length determined to erect a new cathedral, Sir Christopher Wren was nominated to the superintendence. To form a just estimate of the talents of the architect employed in conducting a work of such magnitude and national importance, it is necessary to consider those preliminary steps and contemporary opinions which must ever influence or control the proceedings of an architect. We shall, therefore, condense from his posthumous collection, the *Parentalia*, an account of the formation of the design of the present church.

Before the great tax upon sea-coal, which did not commence till May, 1670, it was expected that the expenses of the building would be defrayed by voluntary contributions alone, and therefore it seemed expedient to restrict the plans to an edifice of moderate bulk. Upon these considerations, the architect prepared a design and model of a structure, with a choir, vestibule, porticos, and a lofty dome. This was applauded by some persons as containing all that was necessary for the church of a metropolis, being of a beautiful figure, and capable of erection at an expense that might reasonably have been compassed; but being designed in the Roman style, it was not so well understood and relished by others, who thought it deviated too much from the old cathedral form; while some wished for more magnificence, and were unwilling that the principal church in London should be inferior to any similar structure on the continent. The architect, enlarging his ideas, endeavoured to gratify the connoisseurs and critics with a grand colossal design, after the best style of the Greek and Roman architecture. This being much admired by some persons of distinction, a highly-finished model in wood, with all its proper ornaments, was made, which was carefully preserved, and at length deposited in a room over the morning-prayer chapel of the present edifice. Sir Christopher always appeared to set a higher value on this design than on any other he had made; but the prevailing prejudices still interfered, and the architect finally turned his thoughts to what was called a cathedral-form, but so modified as to reconcile, as nearly as possible, the Gothic to the new mode of architecture. Thus the design of the present edifice was formed; and, being approved of by king Charles II., a warrant was issued under the privy seal for beginning the work, May 1, 1675. The first stone was laid on the 21st of June following; and the works were prosecuted with so much vigour, that, within ten years from the commencement, the walls of the choir and side aisles were finished, with the circular porticos at the north and south sides, and the great pillars of the dome, were conducted to the same height. Some difficulties now occurred in procuring funds for the prosecution of this great work, but, through the operation of the coal duties, they all vanished; and, in the year 1710, the last, or highest stone, at the top of the lantern, was laid by Mr. Christopher Wren, son of the architect. Thus, by a fortune unusual to edifices of such magnitude and labour, this church was completed in thirty-five years, under the direction of one architect; and, as it has been commonly remarked as a singular coincidence, by one master-mason, Mr. Strong; and under one bishop of London, Dr. Henry Compton.

On investigating the exterior of St. Paul's cathedral, we find the general form to be that of a Latin cross, with an additional arm, or transept, at the west end, to give length to the principal point, and a semicircular projection at the east end, for the altar; there are also at the north-east, south-east, north-west, and south-west angles of the cross, square projections, which, besides containing staircases and vestries, serve as immense buttresses to the dome. This is extremely different, both in proportion and general effect, to the plan of St. Peter's at Rome, where the cross-shape is scarcely marked externally. The first object of attention is the *western front*, which is distinguished by a portico of two orders, the Corinthian supporting the Composite of grand dimensions and rich arrangement. A noble flight of steps, of black marble, forms a basement to this portico, which is terminated at the summit by a pediment. On each side of the front is a steeple; one serving as a belfry, and the other as the clock-tower: singly considered, these may be said to want repose, but yet they are picturesque; and their springing forms not only harmonize with the cupola in the distant view, but also give effect and elevation to the western front, to which they particularly belong. Nor are they without parts of considerable beauty.

The entablature of the upper order is remarkable, from the consoles of the cornice occupying the whole of the frieze. In this, as in many other instances, we see Sir Christopher

sacrificing a particular, to a general, effect; for this cornice, considered as the grand termination to the body of the building, required to be treated in a bold and striking style, rather than with that delicacy appropriate to the order. The idea of this may probably have been taken from the upper entablature of the Coliseum at Rome, where the same motives of general effect have prevailed.

The ornaments of the front are well executed; and though not remarkable for elegance, are placed with judicious frugality, so as to enrich without overloading or confusing the aspect. A very large composition in basso-relievo, representing the conversion of St. Paul, occupies the tympan of the pediment. This is said to be the best work of the artist, Francis Bird. At the apex of the pediment is placed a gigantic statue of the patron saint, while St. Peter, St. James, and the four Evangelists, occupy situations at his right and left hand.

The rest of the building is a vast fabric of a wall decorated with coupled pilasters, arranged at regular distances; the intervals below being occupied with large windows, serving to light the side aisles, and those above with niches; in the pedestals of which are singularly inserted windows, belonging to galleries and rooms over the side aisles.

In the whole surface of the walling, the joints of the stones are marked by horizontal and perpendicular channels; a simple decoration, which, while it gives a vigorous expression of strength and stability, has the advantage of defining and rendering conspicuous the pilasters and entablatures.

The entrance doors of the transepts are adorned by semicircular porticos; objects equally beautiful, whether considered separately or in connection with the total mass of the building, which they adorn and diversify, by the contrast of curves and straight lines, and of insulated columns, with engaged pilasters.

At the centre, formed by the crossing of the nave and transept, rises an ample cupola, which is the most magnificent feature of the building. The basement of this part of the fabric is an octagonal wall, pierced through each side by an arcade; the two, which are in the direction of the nave, are open to the top, as are also the two in the direction of the transept: the other four have an intermediate arch, which supports the continuation of the dado or panelling above the entablature. The spandrels of the arches are spherical, and form a complete circle at the level of the summit of the arches. Upon the archivolt of the arches is placed a corbelled cornice of considerable projection, the upper side forming the floor of the whispering-gallery; from the floor of the whispering-gallery rises a cylindrical wall, called by the French, *tour du dome*, for which we have no technical expression. This is surrounded by a Corinthian peristyle, so placed as to conceal the projecting buttresses of the cupola; and thus, by a happy combination of profound skill and exquisite taste, a construction adapted to oppose, with insuperable solidity, the enormous pressure of the dome, the cone, and the lantern, is converted into a decoration of the most grand and beautiful character. The idea of this arrangement was, doubtless, taken from the interior of the Pantheon at Rome, to which it bears a striking resemblance.

On the exterior side of the building, the general disposition is divided into eight parts by piers, containing staircases, with two columns attached to the angles of each. The spaces between the piers form eight recesses, having in each two columns, which, at a distance, to a hasty observer, appear to be insulated; but they are in fact joined to the dome-tower, by walls, serving as counterforts. All these buttresses are, however, pierced with arcades, so as to leave a free communication round this part of the cupola. The columns being of a large proportion, and placed at regular intervals, are crowned with a complete entablature, which, continuing without a single break, forms an entire circle, and thus connects all the parts into one grand and harmonious whole. Above the colonnade, but not resting upon it, rises an attic story, with pilasters and windows, from which springs the exterior dome, of a bold contour, well adapted to the rising form of the lofty and elegant lantern by which it is crowned. It has been said, with some justice, that the columns of the cupola are too high in proportion to the body of the building, as they are indeed little less than those of the lower order, but higher than the columns of the upper order. This incongruity would not have existed, had circumstances allowed the architect to construct the main edifice of a single order, extending the whole height of the building; but being baffled in this his original intention, it would have been too great a sacrifice to relinquish the peristyle, the noblest feature of the building, or to materially diminish the cupola.

Comparing the cupolas of St. Peter's and St. Paul's, we shall find that, though the latter has, in a great degree, been the model of the former, there is a material difference in the decorative part, though the general idea of the construction is the same. In St. Peter's the buttresses of the dome-tower, though decorated each with two engaged columns and pilasters projecting from the cylindric wall, destroy the continuity, and render the effect disagreeable. The dome is likewise pierced with three ranges of little dormer-windows, which are suffered to spot and break the surface for the paltry consideration of lighting the interior staircases. The idea, originated in St. Paul's, has been prosecuted in the church of St. Geneviève at Paris, where the appearance of a peripteral temple is completely obtained, as the columns surrounding the tambour are all insulated; but, it is to be lamented, that the dome itself should be so deficient in grandeur of dimensions, and grace of proportions, as to destroy the effect of this beautiful decoration.

Beginning the examination of the interior of St. Paul's at the west end, we find the body of the building, as to the general form, entirely upon the plan of the ancient cathedrals; an edifice of three aisles, divided by piers and arches, and covered with vaulting.

Sir Christopher Wren has not only adopted the form of building practised by the architects of the middle ages, but he has imitated their mode of construction; for the lofty vault of the middle aisle is supported by flying buttresses concealed by an enormous screen wall. The architectural detail is in the Roman style, simple and regular.

"The Romans," says Sir Christopher, "though they sometimes used a hemisphere, as in the exhedræ of the baths, of the tribunes, of the temples, and basilicæ, yet, generally, they used a *plain cylindrical vaulting* where the walls were parallel, or cross-vaulting where the two cylinders intersected in diagonals, as in the Temple of Peace, and in all the theatres, in the passages under the steps. The moderns, whose arches are not circular, use commonly another sort, where the spandrels, resting upon the pillars, spring every way round as their arch rises in sections of circles, parallel to the horizon; that is, in four quadrants described from the angles of a square, and terminated by its sides; and, at the summit, these quadrants come in contact in the middle of the sides, the four curves forming a quadrilateral, each side being convex towards the centre; and the space thus included is filled with tracery work, which gives them great opportunity of divers variations, which I need not insist on. Another way, (which I cannot find used by the ancients, but in the latter Eastern empire, as appears at St. Sophia, and by the exam

ples of all the mosques and cloisters of the Dervises, and everywhere at present in the East, and of all others the most geometrical,) is composed of hemispheres and their sections only; where, as a sphere may be cut in all manner of ways, and that still into circles, it may be accommodated to lie in all positions of the pillars. Let A B C D be a cupola, or hemisphere, resting upon four pillars, from whence arise the four *vertical* arches; to which the sections, being semicircles, must join on all sides, whether A B be equal to B C or not: cut the hemisphere again horizontally, the section will be an entire circle, touching in the keys of the arches, and G, H, K, L will be the spandrels, resting upon the pillars, yet still are parts of the hemisphere; and if the horizontal circle be taken away, you may build upon that circle an upright wall, which may bear a cupola again above, as is done in St. Sophia and St. Peter's, and in all the churches in Rome. I question not but those at Constantinople had it from the Greeks before them. It is so natural, and is yet found in the present seraglio, which was the episcopal palace of old; the imperial palace, whose ruins still appear, being farther eastward. Now, because I have, for just reasons, followed this way of vaulting of the church of St. Paul's, I think it proper to show that it is the lightest manner, and requires less butment than the cross-vaulting, as well as it is of an agreeable view."

We shall now proceed with the description of the other parts of this edifice.

It appears that these domes are of considerable antiquity, and, from the reasons here given from the *Parentalia*, that Sir Christopher Wren was justified in his choice in their adoption; their form is beautiful; and, when investigated, it is truly geometrical. Each wing forms a flat dome, supported by four spandrels; a rich wreath of foliage encircles the base, while the centre and the spandrels afford spaces well adapted, and probably intended, to receive ornamental paintings. The western transept is a beautiful part of the building; here insulated columns and screens of iron-railing separate from the aisles, on either side, the morning-prayer chapel, and the consistory.

In the progress of examination, we come to the intersection of the nave and the transept; and here, instead of four openings, eight are produced, which afford striking and picturesque views in various directions; and, in this respect, St. Paul's differs from every church with which we are acquainted, the cathedral of Ely only excepted. On the other hand, the junction of the aisles with the central area presented difficulties, which have caused various defects and mutilations in the architecture. The central area, as before observed, is an octagon, supported by eight piers, with as many apertures; four of which, terminating the middle aisles, are forty feet wide, while the others are only twenty-eight feet; but this disparity only exists as high as the first order of pilasters; at which height the smaller openings are expanded so as to make the main arches all equal. Spandrels between the arches form the area into a circle, which is crowned by a large cantiliver cornice, partly supporting, by its projection, the whispering-gallery. At this level commences the interior tambour of the dome, consisting of a high pedestal and an order of pilasters, the intervals of which are occupied by twenty-four windows and eight niches, corresponding with the intercolumniations and piers of the exterior. All this part is inclined forward, so as to form the frustum of a cone. From a double plinth above the cornice of the pilasters, springs the interior dome.

The choir is of the same form and architectural style as the body of the church, and is terminated by a semicircular apsis. The stalls, an enclosure, though not remarkable for elegance of design, are valuable for their ornamental carving, which is by the masterly hand of Gibbons.

In surveying the decorative parts of the interior of St. Paul's, it must be acknowledged that the general impression is that of simplicity bordering upon meanness and nudity, a defect which implies no censure on the great architect, who has left his work in that state to receive the ornament of painting and sculpture, which the frugality of following times have withheld.

The few ornaments which exist are, in general, well executed, and disposed with judgment: The soffits of the grand arches, under the cupola, are in the best style of simple and appropriate decoration. The dome is painted by Sir James Thornhill, who has deformed this beautiful vault with an absurd, heavy, and fictitious architecture, serving as a frame to eight pictures, representing so many actions of the patron saint. It is to be lamented, that instead of placing historical paintings in a situation where the spectator can distinguish nothing but the most obvious and general effect, some other system of decoration had not been adopted.

The design of the cathedral of St. Paul has been charged with various defects, the chief of which are the following: A want of proportion between the cupola and the body of the building; the divison of the exterior into two stories, of orders of columns and pilasters nearly equal; and the coupling of the columns in the western front:

In the interior, the omission of the architrave and frieze of the order, in the spaces between the great pilasters of the nave, for the purpose of raising the summits of the arches above the level of the architrave; the circumstance of the tambour of the dome being inclined forward out of the perpendicular; and, lastly, the awkward junction of the side aisles and mutilated arches.

With respect to the general division of the body of the building into two orders of architecture, we have the authority of the architect himself, as expressed in the *Parentalia* and exhibited in his favourite model, in favour of the single order; but, with regard to this, he was obliged to yield to circumstances, as the Portland quarries could not afford stones of the required dimensions; this necessity led to another, viz., the coupling of the order.

On an inspection of the ground plan of the building, it will be seen, that the exterior pilasters are placed at intervals corresponding to the interior piers, an arrangement which could not be deviated from. As to the omission of the architrave of the order, above the arches of the interior, we are informed in the *Parentalia*, that, in this respect, Sir Christopher Wren "always insisted that he had the ancients on his side; and that, in the Temple of Peace, in the great halls of the Baths, and in all the great structures of three aisles, this is done, and for this reason, that in these wide intercolumniations, the architrave is not supposed to lie from one column to another; but, from the column to the wall of the aisle, so that the end of it only will appear upon the pillar of the inside of the great navis." This is a sufficient answer to those rigorous critics, who would subject the composition of a cathedral to the strict rules which limited the Grecian temples; and it shows that the architect had studied those antique models, which, if not in the purest taste in point of ornament, were yet the most analogous, in general form, to the edifice he had to construct. But, though this was the ostensible excuse, it was not the real reason; for, upon referring to the section of St. Paul's, it will be seen, that Sir Christopher has made the pilasters of the interior a little higher than the exterior columns, which could not be much without incongruity; and, wishing to give the arches, opening to the aisles, as much elevation, and consequently

lightness, as the design admitted, he chose to encroach on the entablature of the order; and thus, by a single alteration from general rules, he improved the effect of his building.

According to the large plan, published by Gwyn, the external length of the building, from east to west, exclusive of the projection of the portico, appears to be 502 feet; from north to south, excluding the two circular porticos, 244 feet; the breadth of the western front, 177 ; the diameter of the octagonal area, at the crossing of the nave and transept, 107 ; the diameter of the tambour of the dome, 112 ; and the diameter of the dome itself, 102. The total height, from the pavement of the church-yard, to the top of the cross, is 370 feet. The total expense of the building amounted to £747,954. 3s. which was defrayed by a duty on coals imported into London ; but not less than £126,604. 6s. 5d. was furnished by voluntary contributions, chiefly from the clergy. See *The Fine Arts of the English School*, edited by John Britton, F. S. A.

Sir Christopher was architect of no less than fifty-one parish-churches in the metropolis, besides the cathedral and other public buildings, but of these we cannot speak particularly, we can only mention such as are more deserving of notice.

St. Stephen's, Walbrook, is looked upon by some as Wren's master-piece, not even excepting St. Paul's, and the interior certainly is worthy of much praise both for taste and proportion, although by no means faultless. The exterior of the church, like those of the greater number of his churches, has no pretensions to beauty, being plain even to ugliness, if we except the steeple.

The interior, which approaches a parallelogram in plan, is divided into three aisles, and a cross aisle by four rows of Corinthian columns raised on pedestals ; these support the roof, which is divided into compartments. The central portion of the church is covered by a dome, which is finely proportioned and divided into small compartments, decorated with great elegance, and crowned with a lantern. On the sides, under the lower roofs, are circular windows, but those which light the upper roof are small arched ones; and at the east end are three larger arched windows. The dimensions of the building are :—length 75 feet, breadth 36 feet, height to roof 34 feet, and to lantern 58 feet.

Of the remaining churches, those most worthy of notice are St. Bride's and St. Mary-le-Bow, and these are remarkable more especially for their steeples, a feature introduced by Wren into his churches, and one on which he bestowed his principal care, many of his churches being in other respects little worthy of the praise that has been bestowed upon them.

The steeple of St. Bride's is certainly a very excellent composition. The spire is placed on a lofty tower, is octagon in plan, and consists of four similar octagonal stories placed one above another, and decreasing in dimension as they rise, so as to present a pyramidal appearance. Each tier comprises a single order, having a semicircular-headed aperture on each side of the octagon, and a pilaster at each of its angles, the two lower stories being of the Tuscan order, the third Ionic, and the fourth Composite. Above these is a smaller story, which is surmounted by a small spire. The present height of this steeple is 226 feet, but it was originally eight feet higher, the difference having been deducted after an accident by lightning in 1764.

The spire of St. Mary-le-Bow rises in a similar manner from a lofty square tower ; from a stylobate, on the top of which rises a circular peristyle surmounted by entablature and balustrade. Upon this rises above each column a kind of buttress assuming in profile a curve of double curvature, and falling inwards towards the summit, so as to diminish the horizontal area. Above this is another peristyle with entablature and buttresses of a similar form above, supporting a small spire which carries the vane. This steeple is deservedly admired.

We must pass by Wren's other churches, and content ourselves with enumerating some few of his other works, amongst which the most conspicuous in this style are—Greenwich Hospital, Theatre at Oxford, College of Physicians, and Temple Bar.

Of all Wren's pupils, only one attained to any great eminence, and this was Nicholas Hawksmore, one of whose churches, that of St. Mary, Woolnoth, is of considerable merit; this church is thus described by Mr. Godwin. Speaking of the interior, he says—"It is nearly square, and on the model of a Roman atrium. Twelve well-proportioned Corinthian columns, placed three in each angle, at a distance from the outer walls, equal to about one-sixth of the whole width of the church, support an entablature and a clere-story above it, which latter presents a large semicircular window on each of the four sides. The ceiling of the square area enclosed by the clere-story walls, as well as the soffit of the aisles formed by the columns, is profusely decorated with panels and carved mouldings. A ponderous but elegantly ornamented gallery, is introduced on three sides of the church with so much skill, that it does not mar the general effect, as is often, nay, with some few exceptions, always the case.

"The general effect of the interior is rich and beautiful, and the proportions of the plan and section good ; the columns are admirably arranged, and every part displays talent ; the whole design is nevertheless somewhat crowded in detail, and overlaid with ornament, and, according to our view of the case, wanting fitness for its purpose, is less deserving of applause than it would be, were the building otherwise appropriated than it is." St. George's, Bloomsbury, is another church by the same architect.

The next architect of any note practising this style, was James Gibbs, the architect of St. Martin's-in-the-Fields, and St. Mary-le-Strand, both which churches present many good features ; the portico to the former is much admired. Gibbs introduced a practice of placing the spire over the body of the church, so that it appears as if rising out of the roof; this is decidedly objectionable.

Passing by many architects of less note, we arrive at Sir William Chambers, who greatly excelled his cotemporaries and many of his predecessors in this style of building ; his greatest work is Somerset House, which we must not pass by without a short description. "This building," says Mr. Bury, "stands on an area of 800 feet in width, by 500 feet in depth, and is disposed on the four sides of a rectangular court, the interior length of which is 319 feet from north to south, and 224 feet in breadth : the façade towards the Strand is 133 feet long, and consists of three stories : nine arches are assigned to the basement, whereof the three in the centre are open, and lead to the great court, besides having entrances to the apartments of this wing ; the other rusticated arches are occupied by windows, decorated with pilasters, entablatures and pediments. Above this story are two tiers of windows of which those in the lower tier have entablatures supported by Ionic columns ; the upper windows are square, and are surrounded by square architraves. Between these windows, the walls are ornamented with three-quarter columns of the Corinthian order, standing on pedestals, and extending the height of the two stories ; the height of the order without the pedestals is 23 feet, and that of the entablature is 5 feet. Over the three central compartments of this façade, is an

attic-story, with oval windows and statues in front: the entire height from the ground is 62 feet."

The vestibule contains a carriage-way and two foot-ways, separated by two ranges of coupled Doric columns, which with their entablature support the vaults.

The inner front of this division of the building, facing the court-yard, is similar to that in the Strand, with the exception that pilasters are employed in the place of columns.

The east and west sides of this quadrangle are similar to those already described, with the exception of those portions between the extremities and the central division, in which the windows are of a less ornamented description, being rectangular, and without architraves. The central divisions are crowned by urns surmounting the entablatures, and have each a small clock-tower above the roof. The south façade is similar to the east and west sides, but its central compartment is more highly enriched, the entablature being supported by four columns and four pilasters, both of the Corinthian order, and the windows between the columns being recessed. Above the roof is a lofty cupola, partially screened by an angular pediment.

"The front towards the river Thames, is 350 feet long, and presents a magnificent appearance. Its arrangement corresponds with that of the quadrangle, but a superior boldness of character has been adopted in its centre wings, where disengaged columns with pilasters are introduced. The centre part of this building is crowned by a cupola, as above stated. Before this façade is a terrace 50 feet wide, supported by a lofty arcade, and protected by a balustrade. In the centre is one great semicircular arch, and near each extremity is a water-gate of similar form, the piers of which are ornamented with rusticated columns."

We must now turn to a class of structures which have risen up of late, and to which this style of building is peculiarly applicable,—we allude to Club-houses. Some of these edifices are of very elegant design, and of magnificent appearance, their general treatment being borrowed from the palatial edifices of Italy: they are in our opinion the most favourable examples of Italian architecture in England, and are far preferable to the ecclesiastical edifices built in this style; a fact which arises, as we imagine, not so much from the merit of the architects employed, as from the circumstance that the style is adapted to the one class of edifice, and not to the other.

Of the clubs, all of which are of considerable merit, a full account has been given under the article Club-House, to which we beg to refer. We can here only call especial attention to the Reform, the Traveller's, the Carlton, the Army and Navy, and the Conservative. The dignified repose of the first, the simple and unpretending elegance of the second, and the lightness and magnificence of the rest, are subjects all equally worthy of the young architect's attentive study.

The same style has been applied on a somewhat less magnificent scale, yet with equal success, to many other buildings, amongst which fire and life insurance-offices stand pre-eminent. We can here only allude, in passing, to those of the Sun, Imperial, and Globe Societies. This style has also recently been adopted for private mansions, an example of which is afforded us in Bridgewater House, the mansion of the Lord Ellesmere, now erecting under the able superintendence of Mr. Barry, to whom we are indebted for some of the most beautiful and recent erections in this style, amongst which stand pre-eminent the Reform and Traveller's club-houses. We conclude this article with a description of this last, and not least, beautiful example of Mr. Barry's taste, and trust that this may be only a commencement of a new class of town residences for the nobility of this country.

The plan of this mansion is nearly square, the north front being 142 feet 6 inches from east to west, and the west front, shown in our engraving, 122 feet from north to south. The west elevation consists of three stories, separated from each other by ornamental flat-bands and cornices, and is divided into a centre and two wings, which, however, project but slightly. The lower story is rusticated with vertical and horizontal channels, and comprises seven windows, of which five, belonging to the central portion of the building, are plain rectangular apertures, with projecting key-stone, but without architrave. The two outer ones are of a similar character, but are of three lights, the central one being of the same description as the others, and the side ones a little narrower. Above the cornice of this story is a podium, pierced with balusters opposite each window, and having projecting plinths under the architraves. The same number and arrangement of windows occur in this story, but they are of a much more elaborate description, having a highly enriched architrave, and being surmounted by a segmental pediment, supported on projecting corbels, and having the tympanum enriched with sculpture. The triplets in the wings are similarly ornamented, but have a segmental pediment over the central light only, the upper mouldings being continued horizontally, with the cornice over the side lights. The upper story has the same number of square lights with moulded architraves, the spaces between them being panelled: the triple arrangement in the wings is preserved in this story. The entire building is surmounted by a bold cornice supported on consoles, the spaces between which are ornamented with roses, and the corona with dolphins' heads, one over each console. Above the cornicione is a balustrade, the dies of which are surmounted by roses. The angles of the building are finished with coins, which are enriched with reticulated rustication, and, being of considerable width, impart a very rich effect to the façade; the chimneys are brought up at the angles, and are made to form architectural features. A balustrade runs along in front of the lowermost story.

The south elevation is very similar to the west, having a series of nine windows, exactly the same as those in the central portion of the western façade, but having no projecting wings, the extreme angles only being rusticated. The entrance porch is in the centre, and is surmounted by vases similar to those above the balustrade.

IVORY, the name given to the substance composing the tusks of the elephant and the walrus, and to the horn of the narwhal, or sea unicorn. Ivory is extensively used in the arts, for making and embellishing numberless small articles of ornament and use. Tables, cabinets, &c., are frequently inlaid with ivory.

J.

JACK, Lifting Jack, in mechanics, a portable machine for raising great weights through a small space. It consists of a rack and pinion inclosed within a strong wooden case, and the power is applied by means of a winch or handle fixed upon the axis of the pinion; the upper end of the rack is formed into two horns, to take the better hold of the article to be elevated; and from the end two prongs project laterally through a longitudinal groove in the case, which are used upon occasions when there is not room to introduce the jack beneath the load. To prevent the labourers being overpowered, there is a racket wheel and pall on the axis of the pinion.

Jack Arch, an arch of only one brick in thickness.

Jack in the Box, a large wooden solid screw, turning in a hollow one, which forms the upper part of a wooden box, shaped like the frustum of a pyramid; it is used by means of levers, passing through holes in it, as a press in packing, and for other purposes.

Jack Plane, a plane about 18 inches in length, used for taking off the rough of the saw, or the irregularities of the axe, and planing off any inequalities, to prepare the stuff for the trying plane.

Jack Rafter, a short rafter, such as those which are fixed to the hips.

Jack Ribs, in a groin, or in a polygonal domic ceiling, are the ribs that are fixed upon the hips.

Jack Timber, any timber that is interrupted in its whole length, or cut short.

Jak Wood, a coarse-grained wood brought from India, sometimes used in cabinet-work and turnery.

JAMBS (French) the sides of an aperture, which connect the two sides of the wall.

Jamb Lining, the two vertical linings of a door-way or aperture, which connect the two walls.

Jamb Posts, such as are sometimes introduced on the side of a door, in order to fix the jamb linings. They are particularly used when the partition is of wood.

It having been noticed by Mr. T. N. Parker how rapidly the lower ends of door posts decayed where they were exposed to wet, he contrived a cast-iron socket for them, which is much used in Shropshire, and might be generally introduced with advantage. These sockets are cast by the Colebrook-dale company; they weigh only 7lbs. the pair, and cost about 2½d per pound.

Jamb Stones, in stone walls, such as are employed in building the sides of an aperture, in doing which, every alternate stone ought to be inserted the whole thickness of the walls.

JANTU, a machine used in Hindostan for raising water for the purpose of irrigating lands.

JAPANNING, the art of painting and varnishing, after the manner practised by the natives of Japan, in the East Indies. It is employed for the purpose of preserving and beautifying various articles, usually of wood and metal, as well as paper, leather, and cloth, when they are properly prepared for the purpose. Those articles we most commonly find japanned, are pieces of household furniture, cabinet-work, boxes of all kinds, trays, screens, &c., and, very generally, those articles made of any of the above-mentioned or similar materials, which it may be desired to preserve from moisture. This it is admirably adapted to effect, from its drying very hard, and being impervious to water at all moderate temperatures, even to boiling in some cases; but it may be employed on any dry substance that is sufficiently inflexible to prevent the japan from being cracked or forced off.

JERKIN HEAD, the end of a roof that is not hipped down to the level of the opposite adjoining walls; the gable being carried higher than the level of the said walls.

JET D'EAU, (French) a fountain, or ornamented jet, throwing up a stream of water to some height in the air. *See* Fountain.

JETTEE, Jetty, or Jutty, (French) the border made around the stilts under a pier, consisting of piles and planks, stones filling up the interstices, to secure the whole foundation.

Also the projecting portion of a building, such as the overhanging story of ancient timber houses.

JIB-DOOR, a door so constructed as to have the same continuity of surface with that of the partition in which it stands. The use of a jib-door is to preserve the symmetry of an apartment, where only one door is wanted, nearer to one end of the partition than the other. Instead of a jib-door, a real door and a false one may be used. Where jib-doors are used, it is obvious that they must be concealed as much as possible.

JOGGLE, the joint of two bodies, so constructed as to prevent them from sliding past each other, by the application of a force in a direction perpendicular to the two pressures by which they are held together. The struts of a roof are joggled into the truss-posts and into the rafters; when confined by mortise and tenon, the pressure which keeps them together is that of the rafter and the re-action of the truss-post. The same is also applied to the step and platform stones of a geometrical stair.

Joggle Piece, the truss-post in a roof, when formed to receive a brace or strut, with a joggle.

JOINER, the workman who joins wood for the finishing of buildings.

JOINERY, in civil architecture, the art of framing or joining wood together, for internal and external finishings of houses; thus the coverings and linings of rough walls, or the coverings of rough timbers, and the construction of doors, windows, and stairs, are joiners' work.

Joinery requires much more accurate and nice workmanship than carpentry; the latter consists only of rough timbers, used in supporting the various parts of an edifice: joinery is therefore used by way of decoration, and being always near to the eye, and consequently liable to inspection, requires that the joints should be fitted together with the utmost care, and the surfaces made smooth.

The wood used is called *stuff*, and is previously formed by the pit-saw into rectangular prisms, which are denominated *battens*, *boards*, or *planks*, according to their breadths. Battens run from two to seven inches wide; boards from seven to nine inches wide; and planks from nine inches to any greater breadth that can be cut out of a piece of wood.

The operations of joinery consist of forming surfaces of various kinds, also of grooving, rebating, and moulding, and of mortising and tenoning; and lastly, of joining two or several pieces together, so as to form a frame or solid mass

Surfaces, in joinery, are either plane or curved, but most frequently plane. All kinds of surfaces are first formed in the rough, and finally brought to a finish by means of appropriate tools.

Grooving consists in taking away a part of a rectangular section from a piece of wood, so as to form a channel of equal breadth throughout, with three surfaces, one parallel, and the other two perpendicular, to that of the wood; which channel is called a *groove;* and thus the piece that would fill the cavity, or which would restore it to its original form, is a square prism.

Rebating consists in taking away a part from a piece of wood of a rectangular section, so as to leave only two sides, one perpendicular, and the other parallel, to the surface of the wood; the cavity thus formed is called a *rebate.* From this definition it is manifest, that a rebate can only be formed by reducing the piece of wood to be rebated at the angle itself, and may therefore be considered as a semi-groove; and thus the piece which would restore the whole to its original form is a square prism, as in grooving.

A mortise is a cavity recessed within the surface of a piece of wood, with four sides perpendicular to the surface, and to each other. The act of making a mortise is called *mortising.*

A tenon is a projection formed on the end of a piece of wood with four plane sides, at right angles to each other, and to a plane, from which it projects, called *the shoulder of the tenon.*

In the following, all pieces of wood whatever are supposed to be rectangular prisms, and the length in the direction of the fibres; two of the sides of every mortise perpendicular, and the other two parallel, to the fibres; and the four sides of every tenon in the direction of the fibres, unless otherwise described: likewise, if two of the surfaces of a piece of wood be of greater breadth than the other two, the latter are called *the edges,* and the former *the sides;* while each line of concourse, formed by two adjacent sides, is called *an arris.*

Moulding consists in forming the surface of a piece by plane or curve surfaces, or by both, in such a manner that all parallel sections may be similar and equal figures.

The first thing to be done in joinery is to select the stuff or boards, which ought to be well seasoned for every purpose in joinery, and then line it out; and if the stuff be not already at the size, as is most frequently the case, it must be ripped out with the ripping-saw, or cross cut with the hand-saw, or both, as may be wanted. The next thing is the planing of the stuff, first upon a side, then the edge squared, and afterwards gaged to a breadth and thickness, should either or both be found necessary.

Two or more pieces of stuff may be fastened together, in various ways, by pins of wood, or by nails; but in work prepared by the joiner for building, the pieces are more frequently joined together by making their surfaces planes, and plastering them over with a hot tenacious liquid, called *glue,* then rubbing the surfaces until the glue has been almost rubbed out, and one piece brought to its situation with respect to the other. The best work is always joined by this method.

When boards are required of a greater breadth than common, several primitive boards must be fastened together edge to edge, either by nailing them to pieces extending across the breadth, or by gluing them edge to edge, or by joining pieces transversely together with small boards, tongued into grooves excavated in the edges.

Two pieces of stuff are joined together at right or oblique angles by a mortise and tenon adapted to each other, and fastened together with glue.

When a frame, consisting of several pieces, is required, the mortises and tenons are fitted together, and the joints glued all at one time, then entered to their places, and forced together by means of an instrument called a *cramp.*

A frame of wood in order to contain a panel, and surround it completely, cannot be made of less than three pieces, unless one or more of them be curved, because less than three straight lines cannot contain a space.

The operation of forming a given surface, by taking away the superfluous wood, is called *planing,* and the tools themselves *planes.*

The first tools used by joiners are *bench planes,* which generally consist of a *jack plane,* for taking away the rough of the saw and the superfluous wood, only leaving so much as is sufficient to smooth the surface; the *trying plane,* to smooth or reduce the ridges left by the jack-plane, and to straighten or regulate the surface, whether it be plane or convex; the *long plane,* when the surface is required to be very straight; and the *smoothing plane,* in smoothing, as its name implies, and giving the last finish to the work.

Besides the bench planes, there are others for forming any kind of prismatic surfaces whatever, as *rebating planes, grooving planes,* and *moulding planes:* but for a more particular description of these and the bench planes, we shall refer to the article PLANE.

The tools employed in boring cylindric holes are a *stock* with *bits,* of various descriptions and sizes, *gimlets,* and *bradawls* of several diameters.

The tools used in paring the wood obliquely, or across the fibres, and for cutting rectangular prismatic cavities, are in general denominated *chisels;* those for paring the wood across the fibres are called *firmers,* or *paring chisels,* and those for cutting mortises are called *mortise chisels.* The sides of all chisels, in a direction of their length, are straight, and the side of a chisel which contains the cutting edge at the end is of steel. The best paring chisels are made entirely of cast steel. Chisels for paring concave surfaces are denominated *gouges.*

Dividing wood, by cutting away a very thin portion of the material of equal thickness throughout, to any required extent, by means of a thin plate of steel with a toothed edge, is called *sawing,* and the instruments themselves are called *saws,* which are of several kinds; as the *ripping saw,* for dividing boards into separate pieces in the direction of the fibres; the *hand saw,* for cross cutting, or for sawing thin pieces in the direction of the grain; the *panel saw,* either for cross cutting, or cutting very thin boards longitudinally; the *tenon saw,* with a thick iron back, for making an incision of any depth below the surface of the wood, and for cutting pieces entirely through, not exceeding the breadth of that part of the plate without the iron back; likewise a *sash saw,* and a *dovetail saw,* used much in the same way as the tenon saw. From the thinness of the plates of these three last saws, it is necessary to stiffen them by a strong piece of metal, called the *back,* which is grooved to receive the upper edge of the plate that is fixed to the back, and which is thereby secured and prevented from crippling. When it is required to divide boards into curved pieces, a very narrow saw without a back, called a *compass saw,* is used; and in cutting a very small hole, a saw of a similar description, called a *keyhole saw,* is employed. All these saws have their plates longer and thinner, and their teeth finer, as they succeed each other in the order here mentioned, excepting the two last, which have thicker plates, and coarser teeth than either the sash or dovetail saws. The external and internal angles of the teeth of all saws are generally formed at an angle of 60 degrees, and the front edge teeth slope backward in a small degree, but incline or recline from the straight line drawn from the interior angle perpendicular to the edge in the plane

of the plate, as the saw may be employed in ripping or in cross cutting, or cutting perpendicular to the fibres. The teeth of all saws, except turning and key-hole saws, are alternately bent on contrary sides of the plate, so that all the teeth on the same side are alike bent throughout the length of the plate, for the purpose of clearing the sides of the cut made by it in the wood.

Of all cutting tools whatever, the saw is the most useful to the joiner, as the timber or wood which he employs can be divided into slips or bars of any size, with no more waste of stuff than a slice, the breadth of which is equal to the depth of the piece to be cut through, and the thickness equal to the distance of the teeth between their extreme points on the alternate sides of the saw, measured on a line perpendicular to them: whereas, without the use of the saw, cylindrical trees could only be reduced to the intended size by means of the axe; in the use of which there would not only be an immense consumption of stuff, but also much greater labour would be required to reduce it to a straight surface.

Joiners use a small axe, called a *hatchet*, for cutting off the superfluous wood from the edge of a board, when the waste is not of sufficient consequence to be sawed.

The above are what are commonly denominated *edge tools*, but there are others required to regulate the forms. All angles whatever are formed by other reversed angles of the same number of degrees; as an exterior angle by an interior one, and the contrary. The instrument for trying right angles is called a *square*, and those for trying oblique angles are called *bevels*. The two sides which form the edge of a square are always stationary, but those of bevels are generally moveable, one leg upon the other, round a joint. In some cases, where a great number of pieces are required to be wrought to the same angle, a stationary bevel, called a *joint-hook*, is used.

When it is required to reduce a piece of stuff to a parallel breadth, an instrument called a *gauge* is used, which consists generally of a square piece, with a mortise in it, through which runs a sliding bar, at right angles, called the *stem*, furnished with a sharp point, or tooth, at one extremity, projecting a little from the surface, so that when the side of the gauge, next to the end which has the point, is applied upon the vertical surface of the wood, with the toothed side of the stem upon the horizontal surface, and pushed and drawn alternately by the workman from and towards him, the tooth will make an incision from the surface into the wood, at a parallel distance from the upper edge of the vertical side on the right hand. This line marks precisely the intersection of the plane which divides the superfluous stuff from that which is to be used.

When a mortise is required to be cut in a piece of wood, a gauge with two teeth is used. The construction of this instrument is the same as the common gauge, except that the stem has a longitudinal slider with a tooth projecting from its end, so that both teeth may be brought nearer, or removed farther from each other, at pleasure; and also to any distance, from the face of the head or guide, within the reach of the stem.

If, when a piece of wood has been planed, it is required to be sawed across the fibres; to keep it stationary during the operation, and to prevent the sides or edges from being bruised, a flat piece of wood with two projecting knobs on opposite sides, one at each end, called a *side-hook*, is used. The vertical side of the interior angle of one of the knobs is placed close to the vertical side, and the under side upon the top of the bench; then the wood is pressed against the knob which projects from the upper surface while it is cutting. But the use of two side-hooks is better, as they keep the piece more steady.

When it is required to cut a piece of wood to a mitre with one side—that is, to half a right angle—joiners use a trunk of wood with three sides, like a box without ends or a top, the sides and bottom being parallel pieces, and the sides of equal heights; through each of the opposite sides is cut a kerf, in a plane perpendicular to the bottom, at oblique angles of 45° and 135° with the planes of the sides; and another kerf is made with its plane at right angles to the two former: this trunk is called a *mitre-box*. When the wood is to be cut, the mitre-box is fixed steady against two side-hooks, and the piece, which must always be less than the interior breadth of the mitre-box, is laid in it, and pressed against its farther interior angle, with the side downwards, to which the saw-kerf is intended to be perpendicular, and in this position it is to be cut. The two kerfs in the sides of the mitre-box are requisite, in order to form the acute angle on the right or left-hand side of the piece, as may be required.

When a piece of wood is required to be made straight in one direction, joiners use a slip of wood straightened on one edge, and thence called a *straight edge*. Its use is obvious; as by its application it will be seen whether there is a coincidence between the straight edge and the surface.

When it is required to know whether the surface of a piece of wood is in the same plane, joiners use two slips, each straightened on one edge, with the opposite edge parallel, and both pieces of the same breadth between the parallel edges: each piece has therefore two straight edges, or two parallel planes. Therefore, to find whether a board is twisted, or its surface plane, the workman lays one of the slips across the one end, and the other across the other end of the board, with one of the straight edges of each upon the surface; then he looks in the longitudinal direction of the board, over the upper edges of the two slips, until his eye and the said two edges are in one plane; or otherwise, the intersection of the plane passing through the eye and the upper edge of the nearest slip, will intersect the upper edge of the farther slip. If it happen as in the former case, the ends of the wood under the slips are in the same plane; but should it happen as in the latter, they are not. In this last case, the surface is said to *wind;* and when the surface is so reduced as for every two lines to be in one plane, it is said to be *out of winding*, which implies its being an entire plane; from the use of these slips they are denominated *winding-sticks*.

Before we proceed to the method of bringing a rough surface to a plane, it is necessary to show how to make a straight edge. And here the joiner must not lose sight of the properties of a straight-line, viz., that which will always coincide with another straight line, however they may be applied together.

The operation of making the edge of a board straight is called by joiners, *shooting*, and the edge so made is said to be *shot*.

Straight edges may be formed by planing the edges of two boards, and applying them together, with their superficies or faces in the same plane; if there be no cavity in the joint, the edges will be straight; if not, the faces must be applied to each other, the edges brought together, and planed and tried as before, until they coincide.

Another mode is by having a plane surface given Plane:—the dges of a board as straight as the eye will admit of, apply the face of it to that of the plane, and draw a line by the edge of the board; turn the board over with the other side upon the plane, bring the planed edge to the line drawn before, and the extremities of the edge to their former places, and draw another line; then, if all the parts of this line coincide with the former, the edge is already straight, but if not, repeat the operation as often as may be necessary.

Another mode is to plane the edge of a board as straight as can be done by the eye, then plane the edge of another board until it coincides with the former; plane the edge of a third board in like manner, to coincide with the edge of the first, and apply their edges together; then, if they coincide, the operation is at an end, but if not repeat till they do.

By any of these methods, the superficies of the boards to be shot are supposed to be parallel planes, not very distant from each other; for if the faces be not parallel, or if the thickness be considerable, the operation will be more liable to error.

To reduce the rough surface of a body to a plane.—This will not be very difficult, when it is known that a plane will everywhere coincide with a straight line.

The most practical methods are the following:—Provide two winding-sticks, and apply them as before directed, making the ends out of winding, if they are not found to be so; then, if all the parts of the surface on which the edges of the winding-sticks were placed are straight, it is evident that the whole surface must be plane. If the surface is hollow between the said lines, one of the ends, or both, must be planed lower, until the surface acquires a small convexity in the length; and then, if straightened between the straight lines at the ends, it will be a perfect plane.

Another mode of forming a plane, supposing the surface to be of a quadrilateral form. Apply a ruler along the diagonals, then, if they are straight, they are in a plane; but if they are both hollow, or both round, the surface to be reduced is either concave or convex, and must be straightened in these directions accordingly.

Lastly, if, by trying across the diagonals with the straight edge, it be found that the one is hollow and the other round, the surface of the board winds. In this case, bring down the protuberant part of the convex diagonal, so as to be straight with the two extremities; then straighten the concave diagonal, by planing either of the two ends, or both of them, according as the thickness of the board may require. Both diagonals being now straight, traverse the wood—that is, plane it across the fibres, until all the protuberant parts between the diagonals are removed; then smooth it by working in the direction of the fibres.

To join any number of planks together, so as to form a board of a determinate breadth, the fibres of each running longitudinal to those of any other.—Shoot the two edges that are to be joined; turn the sides of the boards towards each other, so that the edges that are shot may be both uppermost; spread these edges over with strong glue of a proper consistence, made very hot; one of the boards being fixed, turn the other upon it, so that the two edges may coincide, and that the faces may be both in the same plane: rub the upper one to and fro in the direction of the fibres, till the glue is almost out of the joint; let these dry for a few hours: then proceed to make another joint; continue to join as many boards or planks in the same manner, till the whole intended breadth be made out. If the boards, or planks of which the board is to be composed, be very long, the edges that are to be united will require to be warmed before a fire; and, for rubbing and keeping the joints fair to each other, three men will be found necessary, one at each extremity, and one at the middle. Boards glued together with this kind of cement will stand as long as the substance of the deals or planks composing them, if not exposed to rain or intense heat, provided the wood has been well seasoned beforehand, and the grain be free and straight, and interrupted with few or no knots. When a board which is to be exposed to the weather is to be made of several pieces, the cement to be used for uniting them should not be of skin glue, but of white-lead ground up with linseed-oil, so thin that the colour may be sensibly changed into a whitish cast; this kind of glue will require a much greater time to dry than skin glue. Boards to be exposed to the weather, when their thickness will admit, are frequently tongued together: that is, the edges of both boards are grooved to an equal distance from the faces, and to an equal depth; and a slip of wood is made to fit the cavity made in both: this slip should be made to fill the grooves, but not so tight as to prevent the joint from being rubbed with proper cement.

To glue any two boards together forming a given angle.—This may be accomplished, either by shooting the edge of one board to the whole of the given angle, keeping the face of the other straight; and then, by applying the two surfaces together, and rubbing as before, they will form the angle required; or, if the two edges, being shot to half the given angle, be applied together, and rubbed and set as before, their faces will form the angle required. In both these methods, when only one side of the board is to be exposed to sight, which is most commonly the case, pieces of wood, called *blocks*, are fitted to the inside of the angle, and the sides glued across the joint or legs of the angle, being previously planed for that purpose.

To form wooden architraves for apertures, by giving longitudinal pieces together.—Architraves are sometimes formed of solid pieces, but a better and more economical mode is that of gluing longitudinal pieces together. See ARCHITRAVE. Architraves of the Grecian form, for doors and windows, generally consist of one or two faces in parallel planes, one of which recedes only in a small degree from the other, while the outer edge is terminated with one or several mouldings, which have a very prominent projection. In this case, make a board of sufficient thickness, and in breadth equal to the breadth of the architrave: prepare a slip of wood of a sufficient thickness and breadth for the mouldings on the outer termination of the architrave, and glue it upon the face, close to the edge of the board, with the outer edge flushed therewith. In this operation, two men, at least, will be required to rub the slip to a joint with the board; and as it often happens that the side of the slip, which is to comply with the surface of the board, is considerably bent, it must be nailed down to the board; previously to this, small square pieces of wood, called *buttons*, must be bored with holes, one in each, and a nail put through the hole to the head; then the slip is also to be bored with a bradawl, and the nails, with the pieces thus described, are entered and driven home as far as the buttons will permit. These buttons may be about three-quarters of an inch thick, and the other two dimensions each equal to, or something more than the breadth of the slip. Sometimes the slip is grooved; and the edge of the board tongued, glued, and inserted into the groove, instead of the above method. Or, the two faces may be made of different boards, tongued together at their joining, and the whole afterwards stuck into mouldings.

To form the surface of a cylinder with wood, whose fibres are in planes perpendicular to the axis of the cylinder, such as may be used in a circular dado, or the soffits of wisdom.

METHOD I.—When the dimension of the cylindric surface, parallel to the axis, is not broader than a plank or board. This may be done by bending and gluing several veneers together; the first upon a mould, or upon brackets, with their edges in the surface of the proposed cylinder, parallel to its axis.

This may be accomplished by means of two sets of brackets, fixed upon a board, with a hollow cylindric space between them, of sufficient thickness for taking in the veneers, with double wedges for confining them. If this operation be carefully done, and the glue properly dried, the wedges may be

slackened, and the work will stand well; but it must be observed, that, as the wood has a natural tendency to unbend itself, the curved surface, upon which it is glued, should be somewhat sharper than that intended to be made, to allow for this tendency.

Some workmen form a hollow cradle, and bending the veneers into it, confine their ends with wedges, which compress them together; and by a very small degree of rubbing, with a hammer made for the purpose, the glue will be forced out of the joint.

Method II.—Form a cradle, or templet, to the intended surface, and lay a veneer upon it; then glue blocks of wood upon its back, closely fitted to its surface, and the other joints to each other, the fibres of the blocks corresponding to those of the veneer.

Method III.—Make a cradle, and place the veneers upon it, confining one end of them; spread the glue between the veneers with a brush, and fix a bridle across, confining its ends either by nails or by screws; open the veneers again, put glue a second time between each two, and fix another bridle across them; and in this manner proceed to the other extremity.

Method IV.—Run a number of equidistant grooves across the back of the board, at right angles to its edges, leaving only a small thickness towards the face; bend this round a cradle, with the grooves outwardly, and fill the grooves with slips of wood, which, after the glue is quite dry, are to be planed down to the surface of the cylindric board, which may be stiffened by gluing canvass across the back.

Instead of using a grooving-plane, workmen frequently make kerfs with the saw; but this mode is not so strong when finished, as the uncertainty of the depths of the kerfs, and the difficulty of inserting the slips, will occasion a very unequal curvature.

To bend a board, so as to form the frustum of a cone, or any segmental portion of the frustum of a cone, as the soffit of the head of an aperture.—Find the arch-form of the covering, as shown under the article Envelope; cut out a board to this form, and run a number of equidistant grooves across it, tending to the centre: this being fixed to a templet made to the surface of a cone, finish it in the manner shown in the last method for a cylinder.

To bend boards so as to form a spheric surface.—Make a mould to the covering of a given portion of the sphere in plano, as shown under the article Dome; complete the number of staves by this mould; make a templet or mould to a great circle of the sphere; groove each of the staves across, at right angles to a line passing through the middle, and bend it round the templet; put slips in the grooves; shoot the edges of the staves, so as to be in planes tending to the centre of the sphere; and these staves, being glued together, will form a spheric surface.

To glue up the shaft of a column, supposing it to be the frustum of a cone.—Prepare eight or more staves, as the circumference may require, in such a manner that if the column be fluted, the joints may fall in the middle of the fillets, which disposition will be stronger than if they were to fall in the middle of the flutes.

Now, suppose eight pieces to be sufficient to constitute the shaft of a column: describe a circle to the diameter of each end; about each circle circumscribe an octagon; from the concourse of each angle draw a line to the centre; then draw an interior concentric octagon, with its sides parallel to those of the circumscribing one, the distance between any two parallel sides, on the same side of the centre, being equal to the thickness of stuff intended: and thus the sections of the staves will be formed at each end, and consequently the bevels will be obtained throughout the whole length; any two pieces when joined together having the same angle, though the staves are narrower at one end than at the other.

In order to join the column, glue two pieces together, and when quite dry, glue in blockings to strengthen them: join a third piece to the former two, and secure it also by blockings. In this manner proceed to the last piece but one.

In fixing the last, the blockings must be glued to the two adjacent staves, and their surfaces, on which the last stave is intended to rest, must be all in the same plane, that its back may rest firmly upon them. In closing up the remaining space, the part of the column that is glued together should be kept from spreading, by fixing it in a kind of a cramp, or cradle, while driving the remaining stave to close the joints.

Instead of this mode, some glue up the column in halves, and then glue them together.

When it is necessary to have an iron core, to support the roof or floor, the column must be glued up in halves; in this case, the two halves are to be dowelled together, and the joints filled with white-lead. Instead of a cramp, a rope is used, twisted by means of a lever. In the act of bringing the two halves together, the percussive force of the mallet must be applied upon the middle of the surface of one half, while an assistant holds something steady against the middle of the other, that the opposition may be equal; and by this means, the surfaces will be brought into contact, and form the joint as desired. In this operation pieces of wood ought to be inserted between the rope and column.

To glue up the Ionic and Corinthian capitals for carving.—The abacus must be glued in parts, so that their joints may be in vertical planes. The leaves and caulicoles of the Corinthian capital may be first made of rectangular blocks, and fixed to the vase.

To make a cornice round a cylindric body of the least quantity of wood, when the body is greater than a half-cylinder, and when the members will nearly touch a right line applied transversely.—Draw a section of the cylinder through its axis, and let the section of the cornice be represented upon the cylindric section. Draw a transverse line, touching the two extreme members of the cornice; and parallel to it draw another line within, at such a distance from the former, as may be necessary for thickness of stuff; produce the latter line, till it meet the line representing the axis of the cylinder, and the junction will either be above or below, according as the cornice is applied to the convex or concave sides of the cylinder. This meeting is the centre of two concentric circles, whose radii are the distances between the nearest and farthest extremes of the section of the cornice. This is evidently an application of the method of finding the covering of a cone. When mouldings are got out in this manner, viz., by a piece which does not occupy the space, when set to the place represented by the height and breadth, they are said to be sprung.

When a cornice is to have much projection, the corona, or middle part, is got out of a solid piece, and the parts above and below, or one of them, as may be found necessary, only set to the spring, and supported by brackets.

Another method is to bend veneers round the cylindric surface or surfaces; then work them to their form with moulding planes.

Raking mouldings depend principally upon the nature of a solid angle, properly called *a trihedral*. In a trihedral angle, with two of its planes at right angles to the third, let these two former make an obtuse angle; then suppose a moulding placed in the concourse of the two planes which form the obtuse angle of the solid, and another in the concourse of the two planes which form one of its right angles;

and supposing the section of the moulding which stands in the line of concourse of the obtuse angle to be given, it is required to find the section of the other, so as to mitre in a plane bisecting the remaining right angle of the solid. The trihedral will thus consist of three plane angles, two of which are right angles, and the other obtuse.

Make an angle equal to that formed by the sides of the obtuse-angled plane of the solid; let one of the legs be called the *mitre-line*, and the other the *raking-line;* draw the position of the moulding at the point of concourse in respect of the mitre-line without the angle; take any number of points in the curve of the moulding; through these points draw lines parallel to the mitre-line: also draw lines through the same points parallel to the raking-line: draw a line perpendicular to the mitre-line, cutting the other parallels at right angles; take the perpendicular, thus cut into several portions by the parallels of the mitre, and transfer it upon any part of the raking-line, marking all the points of section: through the points of section, draw lines at right angles to the raking-line, to cut its respective parallels; through the points of section of the parallels and perpendiculars of the raking-line, draw a curve which will be the section of the moulding.

The raking-mouldings in pediments depend upon this. The raking-line is the top of the tympanum; the mitre-line, the angle of the building; and the line of concourse of the obtuse angle of the solid, the level returning cornice, at right angles to the tympanum, or plane of the front of the building.

The same is also applicable to a hollow trihedral, such as the inside of a room, of which the two vertical planes are at right angles to each other, the legs of the one plane forming a right angle, and those of the other an obtuse angle; and consequently the ceiling, which is the third side of the trihedral, will be inclined to the horizon, like the exterior side of a pediment, or triangular roof, with this difference, that the surface of the former is opposed to the floor, and the latter to the sky. Open pediments are not now in use, otherwise it might be shown how the return mouldings were to be formed: if, however, the above general description is well understood, the reader cannot be at a loss to apply the principle to finding the section of such return moulding in an open pediment also. This, however, will be noticed under the article Moulding.

In a trihedral solid, with two of its planes at right angles to the third, as in the preceding case, let the two planes make an acute angle instead of an obtuse one; then the other two angles of the solid will be both right angled, as also each of the planes forming the acute angle: now supposing one moulding to be placed in the line of concourse of the acute angle of the solid, and another in the line of concourse of one of the right angles; then if these mitre together upon a plane, passing along the line of concourse of the planes which form the remaining right angle of the solid, they will show the principle of the formation of the angle-bars of a bow-window, consisting of three or more vertical planes. As the angle-bar stands in the concourse of two of the vertical planes, suppose those two planes to be cut by a third plane at right angles to their line of concourse, and the solid thus formed again divided in halves by a plane passing along the concourse of the two vertical planes, bisecting the angle-bar, or the angle of their inclination, two equal trihedrals will be formed, each having one acute angle and two right angles: and the mouldings formed on the two legs of the front plane will be those required to mitre together. One of these mouldings will be half of the angle-bar, and the other half of the horizontal-bar.

The section of the horizontal-bar being given, to find that of the angle-bar.—Lay down the horionztal side of the trihedral, viz., that side which is contained by the acute angle; then calling one of the legs *the mitre-line*, and the other *the sash-line;* draw half the section of the horizontal bar perpendicular to the sash line, with the surface of the moulding opposed to the mitre line; take any number of points in the curve of the moulding, and draw lines through them perpendicular to the sash-line, cutting it in as many points; take the length of the intercepted line between the extreme points, and transfer it upon a line perpendicular to the mitre-line, with the several points of division from the mitre-line towards the section of the horizontal-bar; through the several points of division in the said perpendicular, draw lines parallel to the mitre-line; again, through the several points of division in the curve of the section of the horizontal-bar, draw lines parallel to the sash-line, cutting the respective lines parallel to the mitre-line, and the points of intersection will give the section of half the angle-bar, by drawing a curve through them. The counter part being drawn on the other side of the mitre-line, the whole section of the angle-bar will be complete.

The reader will perceive that this principle is similar to the former, both depending upon the trihedral, or solid angle, consisting of three plane angles. The mitre passes through one of the lines of concourse, and a moulding along each of the two others. In both cases, that which is perpendicular to the other two is laid down.

A circular sash-frame in a circular wall, is a solid of double curvature; its formation, therefore, depends upon the section of a cylinder, and the covering of any portion of the cylinder.

The gluing up of the arecular bars depends upon the development of any portion of a cylindric surface.

The radial bars are portions of different elipses, which intersect each other in one common line of concourse, or conjugate axis, being the sections of a cylinder at different inclinations, all passing through a line at right angles to the axis.

Two of the sides of these bars are plane surfaces, and the other two curved surfaces are cylindrical; consequently they terminate the plane surfaces in curved lines, which are portions of elliptical figures.

The head of the sash is generally got out of the solid in halves, or in four pieces, according to the size of the window; and when put together, ought to be so formed, that one concave surface may saddle upon a cylinder of a radius equal to that of the inner circle, which forms the plan, while the outer surface is everywhere equidistant from the cylindric surface; and that the other concave surface may coincide with the convex surface of another cylinder, whose radius is equal to that required to describe the interior curve of the sash-head, while the outer surface is everywhere equally distant from the cylindric surface.

An enlarged or diminished cornice has its parts, in height and in projection, of the same proportions as those of another, already given. Here it is only necessary to suppose the height or projection given; thus, take one of them as the height to be given, and find a fourth proportional to the following three measures, placed in order, viz., the height of the given cornice, the height of the required cornice, and the projection of the given cornice; then divide the height of the required cornice in the same proportion as the height of the given one, and the projection of the one required, in the same proportion as the projection of that given.

The drawing of the flutes of a diminished pilaster, with curved sides, depends also upon the division of a line in the

same proportion as one already divided: thus, a line equal to, or longer or shorter than the breadth of the pilaster, may contain the aggregate breadths of the number of flutes and fillets, in just proportion; then drawing several equidistant lines parallel to the base on the surface of the pilaster to be fluted, divide each of these equidistant lines in the same proportion; then a curve being drawn through each set of corresponding points will be the terminations of the flutes and fillets. For this purpose, an equilateral triangle, with one of its sides divided into the number of flutes and fillets, is sometimes used; for if lines be drawn to the point of concourse of the other two sides, any line parallel to the base will be divided in the same proportion as the base, which must be equal to, or greater than, the breadth of the pilaster at the bottom. The same may also be conveniently done in the following manner: divide a straight line, equal to, or shorter, than the breadth of the pilaster at top; through the points of division draw lines parallel to each other, making any angle with the divided line: then if this series of parallels be intersected by a line drawn in any direction, such line will be divided in the same proportion as the given line. Suppose, therefore, the parallels to be at right angles to the given line: to divide any line on the surface of the pilaster, take the extension of the line, and apply one end of it from any point in one of the extreme parallel lines as a centre, and describe an arc cutting the most remote of the parallel lines; then a line drawn from the centre to the intersection of the arc and the remote parallel, will be divided in the same proportion, equal to the breadth of the pilaster at the place required; then transfer the line so divided, upon the line on the surface of the pilaster. In like manner, may every other line on the surface of the pilaster be divided, and the curve drawn as before.

The method of diminishing and giving a graceful swell to the shaft of a column, depends upon the parabolic or sinical curve; both of which are easily described. The concoid of Nicomedes is also sometimes employed for this purpose; but the instrument required to describe it is very cumbersome, and the curve produced is not of a better form than that of the parabola, or figure of the sines.

Of joining boards.—A simple board, in its original state from the saw, is in one piece. A compound board is formed of several boards.

Boards may be joined together at a given angle, in various ways; by nails or pins, or by mortise and tenon, or by indenting them together; the latter mode is called *dovetailing*, from the sections of the projecting parts, and those of the hollows, being formed to that of a dovetail.

Dovetailing is of three kinds, viz., common, lap, and mitre: common dovetailing shows the form of the pins or projecting parts, as well as of the excavations made to receive them. Lap dovetailing conceals the dovetails, but shows the thickness of the lap in the return side, which appears like the edge of a thin board. Mitre dovetailing conceals the dovetails, and shows only a mitre on the edges of the planes at their surface of concourse; that is, the edges in the same plane, the seam or joint being in the concourse of the two faces, making the given angle with each other. Dovetailing is used in fixing very wide boards together, where the seam or line of junction is in the concourse of the two faces, and the fibres of the wood of each board are perpendicular to a plane passing through such line.

Concealed dovetailing is particularly useful where the faces of the boards are intended to form a saliant angle; but where the faces form a re-entrant angle, common dovetailing will best answer the purpose, as it is not only stronger and cheaper, but is entirely concealed, the dovetails only showing upon the saliant angle.

Indeed, where the faces form a re-entrant angle, and each board is to be fastened to a wall, the two boards may be fixed together by means of a groove in the one and a tongue in the other; and if well nailed previous to their being brought to their situation, so that the nails may not be seen in the faces, this will answer as good a purpose as dovetailing.

When several simple boards are glued together, to form a broad face, they are sometimes strengthened by fixing another simple board across the end, or across each end, as may be required, by means of a groove and tongue, or by mortise and tenon, and reducing the face of the whole compound board to a plane; the transverse pieces are called *clamps*, and the compound board is said to be *clamped.*

In simple and compound boards, where the faces are required to form an angle, and where the fibres of the wood are required to be parallel to the line of concourse of the two planes or faces which form the angle, the two boards are fastened together by tonguing the edge of one of them the whole of its length, and running a groove in the face of the other next to the edge to receive it, so that when the two boards are joined together, the re-entrant angle shows only a line at the concourse of the two surfaces, but the saliant angle shows a line parallel to the line of concourse, which is the intersection of the inner surface of one board produced to meet the external surface of the other; so that to form the saliant angle, the thickness of one board must be added to the breadth of the other, and thus the face of the one is lapped upon the edge of the other the whole of its thickness.

The most common way of joining boards with the fibres thus disposed, in respect of the line of concourse of their inclination, is by lapping the face of one upon the edge of the other, and fastening them together with nails, driven through the lap into the substance of the other.

Besides what has now been treated of, as principles on which the practice of joinery depends, many particulars relating to the art, the definitions of the terms, and several articles which require long description, and a reference to plates, will be found under the following alphabetical order viz.:

Blockings
Boarded Floors
Bolt
Boxing of a Window
Brackets for Shelves
Brackets for Stairs
Brads, in Joinery
Butt-Hinges
Butt-Joint, in Hand-Railing
Cap, in Joinery
Cased Sash-Frames
Casements
Casting, in Joinery
Centre of a Door
Chamfering
Cheeks of a Mortise
Circular
Circular Work
Clamp
Clamping
Cloak-Pins and Rail
Communicating Doors
Curtail Step
Cut Brackets
Cut Standards
Cylindrical Work
Deal
Description
Diminished Bar
Diminishing Rule
Dog-legged Stairs
Doors, framed
Double-hung Sashes
Dovetail
Dovetailing
Draw-bore
Draw-bore Pins
Dressings
Elbows of a Window
Face-Mould
Falling Mould
Feather-edged Boards
Fence
Fillet
Flaps
Floor
Folding Doors
Folding Joint
Folds
Fox-tail Wedging
Frame, in Joinery
Franking
French Casements
Frieze Panel
Frieze Rail
Furniture

Gage
Grounds
Hand-Rail
Hand-Railing
Hanging of Doors
Hanging Stile
Heading Joint
Hinges
Hinging
Housing, and
Impages.
Gluing up of a Base refers to Base; Bridge-Board refers to Notch-Board; Curtail Step refers to the article Stair; Dog-legged Stairs refers to Staircasing; and Inlaying refers to Marquetry and Veneering. Among the foregoing articles, Boarded Floor, Floor, Boxing of a Window, and Description, are of considerable length; Hand-Railing and Hinging are complete articles, accompanied with plates.

Anything omitted in the foregoing catalogue will be explained in the subsequent part of this article.

Mouldings.—The names of moulding in joinery, according to their situation and combination, in various pieces of joiners' work.

Figure 1, edge, said to be rounded.

Figure 2, quirked bead, or bead and quirk.

Figure 3, bead and double quirk, or return bead.

Figure 4, double bead, or double bead and quirk.

Figure 5, single torus.

Figure 6, double torus. Here, it is to be observed, that the distinction between torus mouldings and beads, in joinery, is, that the outer edge of the former always terminates with a fillet, whether the torus be double or single, whereas in beads there is no fillet on the outer edge.

Figure 7, 8, 9, single, double, and triple reeded mouldings; semi-cylindric mouldings are denominated *reeds*, either when they are terminated by a straight surface equally protuberant on both sides, as in these figures, or disposed longitudinally round the circumferance of a shaft; but if only terminated on one side with a flush surface, they are then either beads or torus mouldings.

Figure 10, reeds disposed round the convex surface of a cylinder.

Figure 11, 12, 13, fluted work. When the flutes are semicircular, as in *Figure* 11, it is necessary that there should be some distance between them, as it would be impossible to bring their junction to an arris; but in flutes, whose sections are flat segments, they generally meet each other without any intermediate straight surface between them. The reason of this is, that the light and shade of the adjoining hollows are more contrasted, the angle of their meeting being more acute than if a flat space were formed between them. See *Figures* 12 and 13.

Figure 14, simple astragal, or half round bar, for sashes.

Figure 15, quirked astragal bar.

Figure 16, quirked Gothic bar.

Figure 17, another form of a Gothic bar.

Figure 18, double ogee bar. This and the preceding forms are easily kept clean.

Figure 19, quirked astragal and hollow. Bars of this structure have been long in use.

Figure 20, double reeded bar.

Figure 21, triple reeded bar.

Figure 22, base moulding of a room, with part of the skirting. When the base mouldings are very large, they ought to be sprung, as in this diagram.

A. The base moulding.

B. Part of the plinth.

In order to know of what thickness a board would be required to get out a moulding upon the spring, the best method is to draw the moulding out to the full size, then draw a line parallel to the general line of the moulding, so as to make it equally strong throughout its breadth, and also of sufficient strength for its intended purpose.

Figure 23, a cornice. The part A forming the corona, is got out of a plank.

B. A bracket.

C. The moulding on the front spring.

D. A cover board forming the upper fillet.

E. A moulding, sprung below the corona.

F. A bracket.

Shutters to be cut must first be hung the whole length, and taken down and cut: but observe that you do not cut the joint by the range of the middle bar, but at right angles to the sides of the sash-frame; for unless this be done, the ends will not all coincide when folded together. In order to hang shutters at the first trial, set off the margin from the bead on both sides, then take half the thickness of the knuckle of the hinge, and prick it on each side, from the margin so drawn towards the middle of the window, at the places of the hinges, put in brads at these pricks, then putting the shutter to its place, screw it fast, and when opened, it will turn to the place intended.

Mouldings are mitred by means of a templet, which is a small piece of wood, moulded in a reverse form to the mouldings that are to be mitred, so that the surface of the templet may coincide with that of the surface of the moulding, and to a portion of the plane surface of the framing, both on the face and on the edge adjoining: the ends of the templet are cut to an angle of 45 degrees in a plain perpendicular to the face, the one end forming a right angle with the other.

To scribe one piece of board or stuff to another.—When the edge end, or side, of one piece of stuff is fitted close to the superficies of another, it is said to be scribed to it. Thus the skirting boards of a room should be scribed to the floor. In moulded framing, the moulding upon the rails, if not quirked, are scribed to the styles, and muntins upon rails.

To scribe the edge of a board against any uneven surface.—Lay the edge of the board over its place, with the face in the position in which it is to stand, with a pair of stiff compasses opened to the widest part, keeping one leg close to the uneven surface, move or draw the compasses forward, so that the point of the other leg may mark a line on the board, and that the two points may always be in a straight line, parallel to the straight line in which the two points were at the commencement of the motion: then cut away the wood between this line and the bottom edge, and they will coincide with each other.

To rebate a piece of stuff.—When the rebate is to be made on the arris next to you, the stuff must be first tried-up on two sides: if the rebate be not very large, set the guide of the fence of the moving fillister to be within the distance of the horizontal breadth of the intended rebate; and screw the stop so that the guide may be something less than the vertical depth of the rebate from the sole of the plane; set the iron so as to be sufficiently rank, and to project equally below the sole of the plane; make the left-hand point of the cutting-edge flush with the left-hand side of the plane: the tooth should be a small matter without the right-hand side. Proceed now to gauge the horizontal and vertical dimensions of the rebate: begin your work at the fore end of the stuff; the plane being placed before you, lay your right hand partly on the top hind end of the plane, your four fingers upon the left side, and your thumb upon the right, the middle part of the palm of the hand resting upon the round of the plane between the top and the end; lay the thumb of your left hand over the top of the fore end of the plane, bending the thumb downwards upon the right-hand side of the plane, while the upper division of the fore-finger, and the one next to it, goes

obliquely on the left side of the plane, and then bends with the same obliquity to comply with the fore end of the plane; the two remaining fingers are turned inwards; push the plane forward, without moving your feet, and a shaving will be discharged equal to the breadth of the rebate; draw the plane towards you again to the place you pushed it from, and repeat the operation: proceed in this manner until you have gone very near the depth of the rebate, move a step backward, and proceed as before, go on by several successive steps, operating at each one as at first, until you get to the end; then you may take a shaving or two the whole length, or take down any protuberant parts.

In holding the fillister, care must be taken to keep the sides vertical, and consequently the sole level: then clean out the bottom and side of the rebate with the skew-faced rebate plane, that is, plane the bottom and side smooth, until you come close to the gauge-lines: for this purpose the iron must be set very fine, and equally prominent throughout the breadth of the sole.

If your rebate exceed in breadth the distance which the guide of the fence can be set from the right side of the plane, you may make a narrow rebate on the side next to you, and set the plough to the full breadth, and the stop of the plough to the depth: make a groove next to the gauge-line: then with the firmer chisel cut off the wood between the groove and the rebate level with the bottom; or should the rebate be very wide, you may make several intermediate grooves, leaving the wood between every two adjacent grooves of less breadth than the firmer chisel, so as to be easily cut out; having the rebate roughed out, you may make the bottom a little smoother with the paring chisel; then with a common rebate plane, about an inch broad in the sole, plane the side of the bottom next to the vertical side, and with the jack plane take off the irregularities of the wood left by the chisel: smooth the farther side of the bottom of the rebate with the skew rebate plane, as also the vertical side: with the trying plane smooth the remaining part next to you, until the rebate is at its full depth. If anything remain in the internal angle, it may be cut away with a fine-set paring chisel; but this will hardly be necessary when the tools are in good order.

When the breadth and depth of the rebate is not greater than the depth which the plough can be set to work, the most expeditious method of making a rebate, is by grooving it within the gauge-line on each side of the arris, and so taking the piece out without the use of the chisel: then proceed to work the bottom and side of the groove, as before. By these means you have the several methods of rebating when the rebate is made on the left edge of the stuff: but if the rebate be formed from the right-hand arris, it must be planed on two sides, or on one side and an edge, as before; place the stuff so that the arris of the two planed sides may be next to you. Set the sash-fillister to the whole breadth of the stuff that is to be left standing, and the stop to the depth, then you may proceed to rebate as before.

To rebate across the grain.—Nail a straight slip across the piece to be rebated, so that the straight edge may fall upon the line which the vertical side of the rebate makes with the top of the stuff, keeping the breadth of the slip entirely to one side of the rebate; then having set the stop of the dado grooving plane to the depth of the rebate, holding the plane vertically, run a groove across the wood; repeat the same operation in one or more places in the breadth of the rebate, leaving each interstice or standing-up part something less than the breadth of the firmer chisel: then with that chisel cut away these parts between every two grooves, but be careful, in doing this, that you do not tear the wood up; pare the bottom pretty smooth, or after having cut the rough away with the chisel, take a rebating plane with the iron set rather rank, and work the prominent parts down to the aforesaid grooves nearly. Lastly, with a fine-set screwed rebating plane, smooth the bottom next to the vertical side of the rebate. The other parts of the bottom may be taken completely down with a fine-set smoothing plane: in this manner you may make a tenon of any breadth.

Stairs.—Are one of the most important things to be considered in a building, not only with regard to the situation, but as to the design and execution: the convenience of the building depends on the situation, and the elegance on the design and execution of the workmanship. A staircase ought to be sufficiently lighted, and the head-way uninterrupted. The half paces and quarter paces ought to be judiciously distributed. The breadth of the steps ought never to be more than 15 inches, nor less than 10, the height not more than 7, nor less than 5; there are cases, however, which are exceptions to all rule. When you have the height of the story given in feet, and the height of the step in inches, you may throw the feet into inches, and divide the height of the story in inches by the height of the step; if there be no remainder, or if the remainder be less than the half of the divisor, the quotient will show the number of steps: but if the remainder be greater than the half of the divisor, you must take one step more than the number shown by the quotient; in the two latter cases, you must divide the height of the story by the number of steps, and the quotient will give the exact height of a step: in the first case you have the height of the steps at once, and this is the case whatever description the stairs are of. In order that people may pass freely, the length of the step ought never to be less than 4 feet, though in town-houses, for want of room, the going of the stair is frequently reduced to 2½ feet.

Stairs have several varieties of structure, which depend principally on the situation and destination of the building.

Geometrical stairs are those which are supported by one end being fixed in the wall, and every step in the ascent having an auxiliary support from that immediately below it, and the lowest step, consequently, from the floor.

Dog-legged stairs are those which have no opening or well-hole, the rail and balusters of both the progressive and returning flights fall in the same vertical planes, the steps being fixed to strings, newels, and carriages, and the ends of the steps of the inferior kind terminating only upon the side of the string, without any housing. For farther particulars, *see* Dog-Legged Stairs.

Bracket stairs are those that have an opening or well, with strings and newels, and are supported by landings and carriages, the brackets mitering to the ends of each riser, and fixed to the string-board, which is moulded below like an architrave.

The same methods must be observed as to taking the dimensions of bracket stairs, and laying down the plan and section, as in dog-legged stairs. In all stairs whatever, after having ascertained the number of steps, take a rod, the height of the story from the surface of the lower floor to the surface of the upper floor: divide the rod into as many equal parts as there are to be risers, then if you have a level surface to work upon below the stair, try each one of the risers as you go on, this will prevent any excess or defect, which even the smallest difference will occasion; for any error, however small, when multiplied, becomes of considerable magnitude, and even the difference of an inch in the last riser being too high or too low, will not only have a bad effect to the eye, but will be apt to confound persons not thinking of any such irregularity. In order to try the steps properly by the story-

rod, if you have not a level surface to work from, the better way will be to lay two rods or boards, and level their top surface to that of the floor, one of these rods being placed a little within the string, and the other near or close to the wall, so as to be at right angles to the starting line of the first riser, or, which is the same thing, parallel to the plan of the string; set off the breadth of the steps upon these rods, and number the risers; you may set not only the breadth of the flyers, but that of the winders also. In order to try the story-rod exactly to its vertical situation, mark the same distances on the backs of the risers upon the top edges, as the distances of the plan of the string-board and the rods are from each other.

[The methods of describing the scroll and all ramps and knees, are described geometrically in the articles HAND-RAILING and STAIRCASING.]

As the internal angle of the steps is open to the end, and not closed by the string, as in common dog-legged stairs, and the neatness of workmanship is as much regarded as in geometrical stairs; the balusters must be neatly dovetailed into the ends of the steps, two in every step; the face of each front baluster must be in a straight surface with the face of the riser; and as all the balusters must be equally divided, the face of the middle baluster must of course stand in the middle of the face of the riser of the preceding step and the face of the riser of the succeeding one. The risers and treads are all glued and blocked previously together; and when put up, the under side of the step nailed or screwed into the under edge of the riser, and then rough-bracketed to the rough-strings, as in dog-legged stairs, the pitching-pieces and rough-strings being similar to those. In gluing up the steps, the best method is to make a templet, so as to fit the external angle of the steps with the nosing.

Geometrical stairs.—The steps of Geometrical stairs ought to be constructed so as to have a very light and clean appearance when put up: for this purpose and to aid the principle of strength, the risers and treads, when planed up, ought not to be less than $1\frac{1}{8}$ inch, supposing the going of the stair, or length of the step, to be 4 feet; and for every 6 inches in length you may add $\frac{1}{8}$ part more; the risers ought to be dovetailed into the cover, and when the steps are put up, the treads are screwed up from below to the under edges of the risers: the holes for sinking the heads of the screws ought to be bored with a centre-bit, and then fitted closely in with wood, well matched, so as to conceal the screws entirely, and to appear as one uniform surface without blemish. Brackets are mitered to the riser, and the nosings are continued round: in this mode, however, there is an apparent defect, for the brackets, instead of giving support, are themselves unsupported, depending on the steps, and are of no other use, in point of strength, than merely tying the risers and treads of the internal angles of the steps together; and from the internal angles being hollow, or a re-entrant right angle, except at the ends, which terminate by the wall at one extremity, and by the brackets at the other, there is a want of regular finish. The cavetto or hollow is carried all round the front of the slip, returned at the end, returned again at the end of the bracket, thence along the inside of the same, and then along the internal angle of the back of the riser.

This is a slight imitation of the ancient mode, which was to make the steps solid all the way, so as to have everywhere throughout its length a bracket-formed section. This, though more natural in appearance, and much stronger, would be expensive and troublesome to execute, particularly when winders are used.

The best mode of constructing geometrical stairs, is to put up the strings, to mitre the brackets to the risers as usual, and finish the soffit with lath and plaster, which will form an inclined plane under each flight, and a winding surface under the winders. In elegant buildings, the soffit may be divided into panels. If the risers are got out of two-inch stuff, it will greatly add to the solidity.

In order to get a true idea of the twist of the hand-rail, the section of the rail, by a plane passing through the axis of the well-hole or cylinder, is everywhere a rectangle; that is, the plum or vertical section tending to the centre of the stair. This rectangle is everywhere of an equal breadth, but not of an equal vertical dimension in every part of the rail, unless that the risers and treads are everywhere the same from the top to the bottom: the height is greatest above the winders, because the tread is of less breadth, and less above the flyers; the tread being there the greatest. If you cut the rail, after squaring it, perpendicular to any of its curved sides, the section will not then be a rectangle, three of the sides will at least be curved. Hence two falling-moulds laid down in the usual way, will not square the rail, though in wide openings they may do it sufficiently near. Nor in squaring the rail can the square ever be applied at right angles to any one of the four arrises, for the edge of the stock will not coincide with the side of the rail, being curved; this would be easily made to appear by making a wreathed part of a rail of unusual dimensions, and cutting it in both directions. Therefore, to apply the square right, keep the stock to the plumb of the stair; and to guide the blade properly, the stock ought to be very thick, and made concave to the plan, so as to prevent the possibility of its shaking or turning from side to side; as a little matter up, or a little down, in the direction of the blade, would make a great difference in the squaring of the rail.

All this might easily be conceived from the cylinder itself, for there is no direction in which a straight line can be drawn on the surface of a cylinder but one, and this line is in a plane passing through the axis of the cylinder, and as the two vertical surfaces of the rail are portions of cylinders, there can be no straight line upon such surface but what must be vertical: all others, from this principle, are curves, or the sections of the rail are bounded by curves, or by a curve on that side.

In gluing up a rail in thicknesses, it will be sufficiently near to get out a piece of wood to the twisted form by two falling-moulds, provided the well-hole be not less than one foot diameter. The thickness of this piece, as is there stated, must be equal to the thickness, or rather the horizontal breadth of the rail, together with the thickness which the number of saw-kerfs will amount to, and also the amount of the substance taken away by planing the veneers. We are now supposing the plan of the rail to be semicircular, with two straight parts, one above and one below, a plan more frequently adopted from motives of economy, than from any property of elegance.

The first thing to be done is to make a cylinder of plank to the size of the well-hole. Draw two level lines round the surface of this cylinder at the top and bottom; upon each of these lines set off the treads of the steps at the end next the well-hole. Draw lines between every two corresponding points at the head and foot, and these lines will be all parallel to the axis of the cylinder. Upon each of the springing lines, and also upon a middle line between these two lines, set the heights of the winders, and the height of one of the flyers above and below, or as much as is intended to be taken off the straight of the rail. Take a pliable slip of wood, straight on one edge, and bend it round; keep the straight edge of it upon the three corresponding points, at the height of the last riser of the flyer; then draw the tread of the first

winding step by the straight edge, from the line where the cylindric part commences, to the first perpendicular line on the curved surface; take the next three points higher, and draw a line between the second and third perpendicular lines, proceed in like manner with the next three higher points, and draw a line between the next two adjoining cylindric lines, and the lines so drawn between each three points will be the section of the treads of the succeeding winding-steps.

Having thus gone through the cylindric part, draw a step at the top, and another at the bottom, and thus the sections of the steps will be completed; draw the hypothenusal or pitch lines of the flyer on the lower part, and that of the upper part, and whatever difference you make in the height of the rail between the flyers and the winders, you must set it up from the nosings of the steps of the winders upon two of the perpendicular lines: draw a line through the two points by bending a straight-edged slip round the cylinder, the straight edge of the slip coinciding with these points; this line will represent the top of the rail over the winders, and the hypothenusal lines at the bottom and top, that of the flyers; then curve off the angles at the top and bottom where the rail of the winding parts meets that of the flyers above and below, and a line being drawn parallel to this, will form the falling-mould. The reason of making the vertical elevation of the rail more upon the winders than the flyers, is, that the sudden elevation of the winders diminishes the height of the rail in a direction perpendicular to the raking line, and by this means persons would be liable to fall over it.

To lay the veneers upon the cylinder, if bed-screws or wedges are used, you may try the veneers first upon the cylinder, screwing them down without glue; prepare several pieces of wood, to lie from 6 to 12 inches apart, according to the diameter of the well-hole, with two holes in each, distant in the clear something more than the breadth of the rail. Then having marked the positions of the places of these pieces on the cylinder, pierce the cylinder with corresponding holes on each side, of the depth of the rail. If the cylinder be made of plank 2 inches thick, it will be sufficient for the screws: but if of thinner stuff, it will be convenient to set it on end upon stools, to get underneath, confining the top with nuts. Unscrew one half, three men being at work, one holding up all the veneers, another gluing, and the third laying them down successively one after the other, until all are glued: screw them down immediately. Unscrew the other half and proceed in like manner, and the rail will be glued up. The glue that is used for this purpose ought to be clear, and as hot as possible; the rail ought likewise to be made hot, as otherwise the glue will be liable to set before all the veneers are put down, and ready for the screws: this operation should therefore be done before a large fire, and the veneers thoroughly heated previous to the commencement, in order that the heat may be as uniformly retained as possible throughout the process. The glue in the joints of the rail will take about three weeks to harden in dry weather.

Doors.—When a board is made to fit an aperture in a wall, for the purpose of preventing ingress or egress at pleasure, it is called *a door*, or *closure*.

Doors are seldom constructed of one entire board, from the difficulty of procuring a simple board of sufficient size; neither are they often constructed of simple boards joined edge to edge, to form a compound board, without having transverse pieces fastened to one side, or being clamped at the ends; as, without such appendages, the door of this construction would be liable to break in the direction of the fibres, or be subject to crack or split, if not entirely seasoned, or when the texture is unequal in consequence of knots, or the resin not being uniformly disposed.

The most common kind of doors are constructed of several simple boards, not fixed with glue, or any tenacious substance, but by nailing transverse pieces upon the back of the boards, laid edge to edge. The transverse pieces, thus nailed, are called *ledges*, or *bars*, whence the door is said to be *ledged*, or *barred*. In this case, one of the edges, at every joint, is beaded on both sides, or at least on the face which is the outside, the ledges being placed to the inside.

Doors of this description are generally employed in the cottages of the poor, or in the out-houses of superior buildings.

Where doors are required to combine strength, beauty, and durability, a frame, joined by mortise and tenon, must be constructed, with one or more intermediate openings, each of which must be entirely surrounded by three or more parts of the frame, which have grooves ploughed in the edges, for the reception of boards to close the openings. When any parts of the framing are intended to lie in an horizontal position, after the door is hung, or fixed upon its hinges, they are called *rails;* if there are more than two rails, the extreme rail next to the floor is called *the bottom rail*, and that next to the ceiling, *the top rail*. Doors are seldom framed with less than three rails; in which case the middle one is called *the lock rail;* but most doors have two intermediate rails, of which the one next to the top rail is called *the frieze rail*. When there are more than two intermediate rails, those between the lock and frieze rails have no particular name. The extreme parts of the frame to which the rails are fixed, are called *stiles*, and the intermediate parts, *mountings*, from their vertical position. The boards by which the interstices are closed, are called *panels*. The stiles are first defined, on account of some doors being made narrower at the top than at bottom, in the manner of ancient doors.

Figure 24.—A four equal-panelled door; this form is only used in common work, and frequently without mouldings.

Figure 25.—A nine-panelled door, with square panels at the top.

Figure 26.—A six equal-panel pair of folding doors, two panels in breadth and three in height.

Figure 27.—A double margin or folding-door, with three panels in height, and two in breadth; being all equal.

Figure 28.—A double margin, or pair of folding-doors, with four panels in height and two in breadth, and with two lying panels below the top rail, and two above the lock rail.

Figure 29.—A ten-panelled pair of folding-doors, five in height and two in breadth, with two lying panels under the top rail, two above the bottom rail, and two in the middle: of this form is the ancient door of the Pantheon at Rome.

Figure 30.—An ancient door, narrower at the top than at the bottom: of this form is the door of the temple of Vesta, at Rome, and that of Erechtheus, at Athens. This construction may be useful for causing the door to rise as it opens, in order to clear a carpet, or to make it shut of itself.

Figures 31 and 32.—Doors of communication, or such as shut out of the way of the floor. *Figure* 31, folds round upon the partition, by means of hanging styles: *Figure* 32, is made to shut occasionally in the partition, so as to be entirely concealed. The two middle parts open, like ordinary folding doors, upon hinges fastened to the extreme parts.

Figure 33.—A jib-door, which when shut may be as much concealed as possible. Jib-doors are used to preserve the uniformity of a room, or to save the expense of a corresponding door.

Doors ought to be made of clean good stuff, firmly put

together, the mitres or scribings brought together with the greatest exactness, and the whole of their surfaces perfectly smooth, particularly those made for the best apartments of good houses; in order to effect this, the whole of the work ought to be set out and tried up with particular care; saws and all other tools must be in good order; the mortising, tenoning, ploughing, and sticking of the mouldings, ought to be correctly to the gauge lines; these being strictly attended to, the work will of necessity, when put together, close with certainty; but if otherwise, the workman must expect a great deal of trouble in paring the different parts before the work can be made to appear in any degree passable: this will also occasion a want of firmness in the work, particularly if the tenons and mortises are obliged to be pared.

In bead-and-flush doors, the best way is to mitre the work square, afterwards put in the panels, and smooth the whole off together, then marking the panels at the parts of the framing they agree to, take the door to pieces, and work the beads on the styles, rails, and mountings.

If the doors are double-margin, that is, representing a pair of folding-doors, the staff stile, which imitates the meeting stiles, must be entered to the top and bottom rails of the door, by forking the ends into notches cut in the top and bottom rails.

Of hanging doors.—Having treated fully on the various kinds of hinges under the article HINGING, we shall here make a few observations upon, and give some rules for, hanging of doors, so as to clear the ground or carpet.

First, Raise the floor under the door as much as may be necessary, according to the thickness of the carpet, &c.

Secondly, Make the knuckle of the bottom hinge to project beyond the perpendicular of the top hinge about one-eighth of an inch: this will throw the door off the floor.

Note.—The centre of the top hinge must project a little beyond the surface of the door, if the hinge is let equally into the door and into the jamb; otherwise, if the centre lie in the surface of the door, it ought to be placed at the very top, which is seldom done, except when hung with centres.

Thirdly, Fix the jamb, on which the door hangs, out of the plumb line, so that the top of the jamb may incline to the opposite jamb about one-eighth part of an inch: this will contribute to the effect of clearing the door from the floor.

Fourthly, Make the door, when shut, to project at the bottom towards the inside of the room, about one-eighth of an inch, which may be effected by giving the rebate the quantity of inclination requisite.

Note.—Although any of the above methods, properly applied, will make a door swing sufficiently clear of the floor, yet as each one separately will require to be done in so great a degree as to offend the eye, I do not recommend it in nice work, but would rather advise a combination of them all to be used, thus:

Raise the floor about one-eighth of an inch under the door; make the jamb on which the door hangs incline to the opposite jamb about one-quarter of an inch; make each rebate that stops the door project at the bottom one-eighth part of an inch to that side of the room on which the door opens. Now these several methods practised in the above small degrees, which will not be perceptible, will throw the door sufficiently out of the level when opened to a square; that is, it will be at least half an inch when the height of the door is double its width.

Fifthly, *Rising hinges*, which are made with a spiral groove winding round the knuckle, answer a similar end; this construction of hinge requires that the door should be beveled at the top next to the ledge or door-catch, as much as the hinge rises in one quarter of its revolution.

Sixthly, This may also be effected by adopting a door in the form of the antique doors; that is, the bottom to be wider than the top, the jambs having the same inclination.

Mouldings of Doors.—The different denominations of framed doors, according to their mouldings and panels, and framed work in general. The figures in the Plates, to which these descriptions refer, are sections of doors, through one of the stiles, taking in a small part of the panel; or they may be considered as a vertical section through the top rail, showing part of the panel.

Figure 34, the framing is without mouldings, and the panel a straight surface on both sides: this is denominated *doors square and flat panel on both sides.*

Figure 35, the framing has a quirked ovolo, and a fillet on one side, but without mouldings on the other, and the panel flat on both sides: this is denominated *doors quirked ovolo, fillet and flat panel, with square back.*

Figure 36, differs only from the last in having a bead instead of a fillet, and is therefore denominated *quirked ovolo, bead and flat panel, with square back.*

Figure 37, has an additional fillet on the framing to what there is in *Figure* 36, and is therefore denominated *quirked ovolo, bead, fillet, and flat panel, with square back.*

Note.—When the back is said to be square, as in *Figure* 35, 36, 37, the meaning is, that there are no mouldings on the framing, and the panel is a straight surface on one side of the door.

Figure 38, the framing struck with quirk ogee and quirked bead on one side, and square on the other; the surface of the panel straight on both sides; this is called *quirked ogee, quirk bead and flat panel, with square back.*

Figure 39, differs from the last, only in having the bead raised above the lower part of the ogee, and a fillet. This is therefore denominated *quirked ogee, raised bead, and flat panel, with square back.*

Figure 40, is denominated *cove, raised bead, and flat panel, with square back.*

Figure 41, is denominated *quirked ovolo, bead, fillet, and raised panel on front, with square back.* The rising of the panel gives strength to the door, and on this account they are often employed in street doors, though the fashion at present is discontinued in the inside of buildings.

Figure 42, the framing is the same as the last, but the panel is raised in front, and has an ovolo on the rising. This is therefore denominated *quirked ovolo, bead, and raised panel, with ovolo on the rising on front of door, with square back.*

Figure 43, is denominated *quirked ogee, raised panel, ovolo and fillet on the rising, and astragal raised on the flat of panel and square back.*

Note.—The raised side of the panel is always turned towards the street.

Figure 44, is denominated *quirked ovolo, bead, fillet, and flat panel, on both sides.* Doors of this description are used between rooms, or between passages and rooms, where the door is equally exposed on both sides. When the panels are flat on both sides, or simply chamfered on one side and flat on the other, and the framing of the door moulded on the side which has the flat panels: such doors are employed in rooms where one side only is exposed, and the other never but when opened, being turned towards a cupboard or dark closet.

Figure 45, is denominated *bead, but, and square*, or more fully, *bead and but front, and square back.* In bead and but work, the bead is always struck on the outer arris of the panel, in the direction of the grain.

Figure 46, is denominated *bead and flush front and*

quirked ogee, raised panel, with ovolo on the rising, grooved on flat of panel, on back. Bead and flush, and bead and but work, are always used where strength is required. The mouldings on the inside are made to correspond with the other passage or hall doors.

Figure 47, is a collection or series of mouldings, the same on both sides, and project in part without the framing on each side. The mouldings are laid in after the door is framed square and put together. If bradded through the sides of the quirks, the heads will be entirely concealed; but observe, that the position of the brads must not be directed towards the panels, but into the solid of the framing. The mouldings of doors which thus project are termed *belection mouldings;* belection-moulded work is chiefly employed in superior buildings.

Geometrical Descriptions in Joinery.

To find the true bevel for hanging any door.

Figure 48.—Let *a* be the centre of the hinge; on *a b* the width of the door, describe a semicircle, *b c e d a*, cutting the other side of the door at *c* and *d*. Join *a d* and *b c*, which will be the proper edges of the door, in order to make it open freely.

Note.—The bevelling on the side *a d* is of no other consequence than to make the sides uniform.

To find the joint for a pair of folding doors.

Figure 49.—Let *h* and *g* be the centre of each hinge; bisect *h g* by a perpendicular, *a b*, cutting the thickness of the door at *a* and *b;* bisect *a b* by the perpendicular *c d* at *e;* make *e c* and *e d* each equal to half the thickness that you intend the rebate to be. Suppose you intended the flap, *g a c d f*, to open, draw a line from *d* to the centre of the hinge at *g;* on *d g* describe a semicircle *d f i g*, cutting the other side of the door at *f;* join *f d*, and through *c* draw *c k* parallel to *d f;* then *k c d f* will be the proper joint.

Note.—If you put a bead at the joint, it ought to be equally on each side of the points *a* and *b*.

To find the bevel on the edge of a door, when it is executed on a circular plan, and the door to turn towards the space on the convex side of the circle.

Figure 50.—With regard to the circular door, all that is required is to make the angle *a b c* either a right angle or greater than a right angle (for a right angle is the least that any door will admit of) formed by the edge of the door, and a line drawn from the centre of the hinge to the opposite angle.

For the folding-doors.

Figure 51.—Let *a* and *b* be the centres of the hinges; join *a b*, and bisect it by the perpendicular *c f e*, cutting the door in *c* and *e;* bisect *c e* by the perpendicular, *g f h;* make *f h* and *f g* each equal to half the thickness of the rebate: join *h b;* on it describe the semicircle *h i k b*, cutting the concave side of the door, *i;* join *i h;* through *g* draw *g l* parallel to it; then will *l g h i* be the joint required.

To find the meeting joint of folding doors when the hinges are placed on the concave side of the doors.

Figure 52.—Let *a* and *b* be the centre of the hinges; join *a b*, and bisect it by a perpendicular, *c d e*, at *c*, cutting the thickness of the door at *d* and *e;* bisect *d e* by a perpendicular, *g f h*, cutting *d e* at *f;* make *f h* and *f g* each equal to half the thickness of the rebate; join *b h;* on it describe a semicircle, *h i k b*, cutting the other side of the door contrary to the hinge at *i;* join *i h*, and through *g* draw *g l* parallel to *i h*, cutting the concave side of the door at *l;* then will *i h g l* be the joint sought.

Demonstration.—Let the door *a l g h i* remain in its place; now the angle *b i h* being a right angle, consequently the perpendicular *b i* will be the shortest line that can be drawn from the point *b* to the line *i h;* then suppose tne half door to be turned round the hinge at *b;* the point *i* will then describe a circle, whose centre is the hinge at *b;* then will *i h* be a tangent to that circle at *i;* therefore the angle at *i* will touch no other part of the edge of the other door, but at *i*.

If round the centre of the door which opens as *Figure* 53, you describe circles on each side of the rebate, and the edges of each door be made circular, it is plain it will also open in this case.

The plan of the doors here shown, are two or three times thicker than those used in practice, in order to show the principle clearly.

Figure 54, a section of the jamb-post, jamb-linings, grounds, and architraves, with part of the plan of a door.

B *b*. Sections of the grounds, flush, or in the same plane with the plaster.

E *e*. Outside and inside architraves.

g g g g. Line of the plinth.

C. Jamb-lining.

H. Hanging style.

I. Door style hung to the hanging style H, by means of the hinge *m*.

Figure 55, half of the plan: showing the door folded back; the parts in this having the same references as those in Figure 54.

Figure 56, meeting styles.

Figure 57, the moulding of the door, shown to a larger size.

This method is advisable where you have no opportunity of making the doors slide into the partition, as is shown in Figure 32; but whenever that opportunity offers, it should be preferred, as no door can be seen when shut into the partition, which not only keeps them entirely out of the way, but makes the most complete appearance.

Elevation of a pair of folding-doors, to be shut quite out of the way, in order to open a communication between two rooms, or to throw both into one on any occasion.

Figure 58, plan of half the door to a small size.

A. Plan of the outside style.

B, C. Plans of the hanging styles.

D. One of the meeting styles.

G G G, *g g g*. Framed partitions, distant from each other, in the clear, the thickness of the door.

F F F. The space or cavity for the door to work in, which must be made sufficiently wide to receive one half of the door entirely within, or nearly so: doors of communication for general uses may be constructed in this larger door, in which case the middle doors may be hung to the flaps, on the flanks, so that they will open like any other common folding-door; this method, therefore, combines utility and convenience, and is a complete deception. The first leaf of the door must run in a groove at the top, to make it steady.

Figure 59, a section of the style next to the partition, to a large size, with part of the plan of the bottom rail, showing a small part of each partition.

Note. In setting out work of this kind for practice, one half of the plan ought to be completely drawn out.

To find the joint of a jib-door, so that it shall open freely at the hanging side, and the joint to be a plane surface.

Figure 60.—Let C, the centre of the hinge, be in the same plane with the dado, and placed within the substance of the lining, in order to give strength to the jamb.

C E. The thickness of the door at the joint, which produce till it cut the opposite side of the base moulding at A; make A B equal to A C; join B C, and from B draw B D perpendicular to B C; then will B D be the true line through which

the surbase-moulding must be cut in a plane perpendicular to the floor. The shadowed part shows a part of the jamb-lining cut out sufficient to let the surbase-moulding move in it.

Note.—If the centre of the hinge had been placed in the plane of the side of the rebate, parallel to the jamb-lining, a deep cavity through the jamb would have been brought into view in the opening of the door, the exposure of which would have been very unsightly.

If the upper part of the door be hinged, the axis of the hinge should be in a straight line with the axis of the centre below, and both the axis of the hinge and the axis of the centre should be in the plane of the face of the door, so that the joint upon the hanging side will always be close.

Figure 61, the elevation of the surbase at the joint.

The construction of a sash-frame, and the manner of putting the several parts of it together.

Figure 62, the elevation of the sash-frame.

A B C D. The outer edge of it.

The dark perpendicular lines E F, G H, are grooves whose distances from the edges L M and K I of the sash-frame, are equal to the depth of the boxing, together with three-eighths of an inch allowed for the margin between the shutters and the bead.

Figure 63, horizontal section of the sides, showing also the plan of the sill.

Figure 64, a vertical section of the sill and top, showing the elevation of the pulley-style *m* and *n*, the pulleys let into the pulley-piece.

Figure 65, the horizontal section of the sides, showing also a plan of the head of the sash-frame.

Figure 66, the elevation of the outer side of the sash-frame: the outside lining being taken away in order to show the work within the sash-frame.

f g, the parting strip fastened by a pin: *e d*, one of the weights connected with the sash by means of a line going over the pulley *c;* the other end fixed to the edge of the sash.

Note.—The weight *d e* is equal to half the weight of the sash.

Figure 67, part of the head of the sash-frame before put together.

Figure 68, the edge of *Figure* 67.

Figure 69, the edge of the bottom, showing the manner of fixing the styles.

Figure 70, the plan of *Figure* 69.

Figure 71 and 72, sections of window-sills, with sections of the under-rail of the sash, showing the best modes of constructing them in order to prevent the weather from driving under the sash-rail.

A. Section of the bottom-rail of the sash.

B. Section of the bead tongued into the sill.

C. Section of the sill.

Figure 73, sections of the meeting-rails, with the side elevations of the upright bars.

C. Rebate for the glass.

D. A square.

E. F. An astragal and hollow moulding.

G. Fillet.

Note.—The small letters denote the same parts of the under-sash.

Figure 74, section of an upright bar, with the plans of two horizontal bars, showing the franking or manner in which they are put together, so as to keep the upright bars as strong as possible. The thickness of the tenon in general comes about one sixteenth of an inch to the edge of the hollow of the astragal, and close to the rebate on the other side.

h h. A dowel to keep the horizontal bars still firmer together.

Note.—The same parts in this have the letters of reference the same as *Figure* 73.

Note also. There is no rebate made for the glass on the inside of the meeting-bar; a groove being made to answer that purpose.

Figure 75.—*Section of common shutters and sash-frame.*

A. Section of the architrave.

B. Ground for the architrave.

F. Back lining of the boxing, tongued into the ground B, and into the inside lining G, of the sash-frame.

G. The inside lining of the sash-frame.

H. The inside bead.

I. The pulley-style.

K. The parting bead.

L. Outside lining.

M. Back lining.

C C C. The front-shutter hung to the inside lining of the sash-frame, G, by means of the hinge *a*.

D D D. Back flap or shutter hung to the front shutter by means of the hinge *b*.

E E E. Another back flap hung to D D D, by means of the hinge *c*.

As in a window, the whole of the light should be shut out, the principle of setting out the shutters is, that each boxing should contain as many shutters as will cover one half; the horizontal breadth of which is from the axis of the hinges to the central vertical line of the windows.

O P Q R. Plan of the lower sash.

O. Rebate of the glass.

P. A square.

Q. An astragal moulding

R. A small square or fillet.

Figure 76, the method of hinging two back flaps together, showing the manner of placing the hinge, when room is scanty in the boxings.

Elevation and plan of half a window, adapted, when the wall of the building is not sufficiently thick to admit of room for boxing.

Figure 77, elevation of half the window.

Figure 78, plan of the window to double the size of the elevation, in order that the parts may be more distinctly seen.

E L. The breadth of the shutter, which is hung to a hanging style G, and the hanging style G is hung to the sash-frame by the hinge at *h*.

The whole breadth of the shutter E L, together with the breadth of the hanging style at G, that is, *i h*, ought to cover exactly half the breadth of the window; viz., from the axis of the hinge at *h*, to the central vertical line of the window.

H. Architrave.

I. Back-ground.

K. Back lining.

The panel A B C D, *Figure* 77, represents the shutter, of which E F, *Figure* 78, is the breadth. The hanging style and shutter are hung together by means of a rule-joint, as before described, under the article HINGING.

Under the shutter A B C D, is a bead R, which is continued across the sash-frame to serve for a capping; P is a vertical bead continued in a line with the edge, at D, of the rule-joint.

O and N. Sub-plinth of window, flush with the bead P.

M. Plinth, or skirting-board.

Figure 79.—A. Architrave-moulding.

B. Ground.

C C C. Back lining.

D. The lining, or return of the window.

E E E. The shutter hung to the hanging style, F, which is hung to the sash-frame by the hinge at *a*.

G. The inside lining of the sash-frame.

H. Inside bead.

I. Parting bead.

K. Outside bead.

L. Back lining.

M. The parting slip for the weights N and O.

N and O. Weights.

P. Ground fixed upon the plug, Q.

Q. The plug for securing the finishings.

R. Pulley-style.

The plan, front, side elevation, and section of a window proper for a building where the walls are not thick enough to admit of room for boxings, which will show the same finish as if the shutters folded into boxings.

Figure 80, front elevation of the window.

The dotted lines *a b d c*, represent a piece of framing.

The other side, A B C D, represents a sliding shutter in the wall.

The framing is supposed to be removed, in order to show the shutter.

Figure 81, the side elevation and section, supposing the shutter removed.

a. An architrave-moulding.

b. Soffit.

c. Top of the sash-frame.

d. Capping, tongued into the sash-frame sill.

Figure 82, horizontal section and plan of the window, twice the size of the elevation.

g g. Section of the framing, as shown by *a b c d*, *Figure* 80, by dotted lines.

h h. Plastering on the wall.

i i. A shutter hung to the sash-frame.

f f. Section of the sliding shutter, which runs on rollers.

k k. A flap, which is let into a rebate and hinged at the edge *p p*, so that when the flap is turned round, the hinges out of the rebate, and the shutter *i i* turned to the face of the window, there will be a clear passage for the shutter *f f* to run out.

Note.—Although there is only a stop for the back of the shutter at the bottom, yet it is quite sufficient, as it is stopped on both sides at the top, and as the edge of the shutter should never be entirely out of the boxing.

This is more clearly shown by the parts drawn larger in the next plate.

Different sections of the foregoing Plate.

Figure 83, horizontal section through the side of the window.

A. Architrave moulding.

B. Part of a piece of framing.

C. Part of the shutter.

D. Plaster or rendering upon the wall.

E. The front shutter hung to the sash-frame at *y*.

F. Back lining.

G. Inside lining of the sash-frame.

H. Inside bead of the sash-frame.

I. Pulley-piece.

K. Parting bead.

L. Back lining of the sash-frame.

M. Parting stripe.

N. Outside lining.

Figure 84, vertical section through the top of the window.

a. Architrave moulding.

T. Ground over the window.

C. Section of part of the shutter.

O. Soffit.

P. Top of the sash-frame.

N. Horizontal outside bead.

h, h. Inside horizontal bead.

Figure 85, vertical section through the sill of the window.

B. Edge of the framing.

C. Edge of the shutter.

Q. Capping, rebated out at S, and tongued into the sash-frame sill.

S. A flap hung to Q, by means of the hinge at *n*; then by turning the front shutter upon the window, and by turning up the small flap, S, there will be a clear passage for the shutter, C, to run in.

Plan, elevation, and section, of a window with shutters, which will show uniform and complete, whether the shutters are in the boxings, or closing the aperture of the window.

Figure 86, plan or horizontal section at *a b*.

Figure 87, elevation or front of the window.

Figure 88, vertical section at C, D, *Figure* 87, and side of the window.

E. Thickness of the pilaster or architrave.

F. A bead stuck on its edge, parting the edge of the pilaster from the shutter.

G. The breadth of the shutter.

H, I. A bead and square to correspond to the thickness of the architrave and bead, so as to show the same finish on each edge of the shutter: one edge of this finishes against the sash-frame above, and the same edge below finishes against the back of the window down to the plinth.

K. Another square, equal to the projection of the capping.

L. Bead of the sash-frame.

M. Thickness for the under sash to run in.

N. Parting bead.

O. The thickness for the upper sash to run in.

P. Outside lining and bead.

Q. The breadth of the reveal or outer brick-work. This is farther explained in another figure, where the principal sections are shown to a larger scale. *a a*. Lintels, made of strong yellow deal or oak.

b. The top of the ground.

c. The architrave fixed upon the ground *b*.

d d. The soffit tongued into the top of the sash-frame *e*, and on the other edge into the head architrave C.

f f. A hollow space between the soffit *d d*, and the lintels *a a*; the under edges of the lintels *a a*, are generally about four inches and a half above the camber of the outside of the window; but it may be less when there is any necessity for it, as, for example, when very narrow grounds are used, it may come down within a quarter of an inch of the soffit.

The face of the pulley-style of every sash-frame ought to project beyond the edge of the brick-work about three-eighths of an inch; that is, the distance between the face of each pulley-style ought to be less by three-quarters of an inch than the width of the window on the outside, so that the face of the shutters ought to be in the same plane with the brick-work on the outside.

Parts of the foregoing at large.

Figure 89. Plan of the shutters.

A. The outside lining.

B. The pulley-style.

C. Inside lining.

D. Back lining.

E, F. Weights.

G. Parting slip of weights.

H. Parting bead of sashes.

I. Inside bead.

K L M N. Plan of the sash-frame.

K L. Sill of the sash-frame.
M. Plan of the inside bead.
N. Plan of the capping.
R R. Hanging style, hung to the sash-frame at *a*.
S S. A shutter, hung to the hanging style at *e*.
T T. Another shutter, hung to S S at *n*, if necessary.
P P. A door, hung to the architrave at *m*, falling upon the hanging style R R by means of a rebate.
Note. The door must fall in a rebate at top and bottom.
U. A ground to fix the architrave upon.
V. The architrave fixed upon the ground.
W. Back lining.

When the aperture is shut, the door P P must be turned round the hinge *m*, parallel to the face of the sash-frame: then the shutters R R, S S, T T, being drawn out and turned on the hinge *a*, and on the hinges *e* and *n*, will cover that part of the window for which they were intended. The door P may then be closed, and the whole will have a uniform and neat appearance.

To find the splay of the ground b c.—Draw a line from the centre of the hinge at *a* to the edge of the ground at *b*; on *a b*, as a diameter, describe a circle cutting the back lining of the boxing at *o*; join *c b*, and it will be the bevel required.

Front and two side elevations of a window, the sash-frame being out of the square, or an oblique-angled parallelogram: showing how to construct the sides of the window, so that the shutters shall make an equal margin round the edge of the sash-frame, when the window is shut: and also to fit their boxings.

Figure 90. Elevation of the window. A B C D being the edge of the sash-frame next to the bead, and E F G H the margin between the shutters and the inside beads.

The difficulty of fitting up a window of this kind may be surmounted if the following observations are attended to: the points K and I, *Figure* 91, being taken at the distance E F, *Figure* 90, and the point R, *Figure* 91, being made to correspond to K, *Figure* 90, the middle of the meeting rails; then make the angle R K L, *Figure* 91, equal to the angle K E H, *Figure* 90; through R and I draw R S and I M parallel to K L; then K I M L will be the front shutter, and R S the parting bead, in case the shutters are to be cut.

Figure 92, is constructed in the same manner as *Figure* 91; that is, by making the angle T O P equal to the angle L H E, *Figure* 90; the points O, T, N, being previously made to correspond to the points H, L, G, as on the other side.

In *Figures* 91 and 92, A and B are lintels.
C. The top of the sash frame.
D. The soffit.
G. Sash-frame sill.
F. Stone sill.

Plan and elevation of the shutters to the foregoing example; showing the manner of hanging and cutting the shutter when the sash-frame is an oblique-angled parallelogram, or out of the square, as workmen call it.

Let *Figure* 93, be the plan of the window, and let A B and D C, *Figure* 94, be the bottom and top ends of the shutters parallel to each other; now, in order that the shutters may fit close into their boxing, and also close into the window-frame, the centres of the hinges to each flap must be set in lines perpendicular to D C or A B.

To set out the shutters.—Make A *e* and D *f*, *Figure* 94, equal to the breadth of the front shutter, and draw the line *f e*; then will A D *f e* represent the front shutter, and *f e* the edge on which the flap will join to it; then if the angle D *f e* be not a right angle but obtuse, from *f* draw *f g* perpendicular to D C; then will *f g* be the line of the hinges. In the same manner, B C *q r* will represent the shutter on the other side; B *r q* being the obtuse angle, and *r s* a perpendicular to A B for the line of the hinges: the two extreme joints being made, all the other joints, *h i*, *k l*, *m n*, and *o p*, ought to be all perpendicular to the ends D C and A B of the shutters: then will the centres of the hinges be parallel to, or in the same line with, the joint.

To find the breadth of the flaps which hang to the front shutters, so that they may be as wide as possible.—From the points A and C, the obtuse angles, draw A *v* C *u* perpendicular to A B and D C, the ends of the shutters; make *v a* and A *b* equal to the breadth of the rebate; and from the point *f*, and in the line of hinges, make *f c*, *f h*, and *g d*, *g i*, respectively, equal to *f a*, *f v*, and *g b*, *g* A; then will *e f h i* be the flap required; and it is plain, from the nature of this window, that the other flap, *o q r p*, must be the same figure as the flap *e f h i*, but inverted.

The other flaps may be filled in as the width of the window will admit.

Note.—We have given this example because the method is general, and will apply to all cases; the workman ought never to trust to the sash-frame being absolutely square, for they seldom are; and if the variation be ever so small, there will be a very considerable error in the ends of the shutters when enclosed in the boxings. Such distorted examples as the above generally occur in old buildings; in such this method must be adopted: but also, for the above reason, it ought not only to be employed in old work, but even in new, where the shutters are cut, so that the ends of the shutters may not only coincide when folded, but also with the sill and top of the sash frame, and also with the meeting rail.

Customary Measures in Joiners' Work, for labour only.

Preparation of boarding by the foot super.—The different distinctions are—edges shot; edges shot, ploughed and tongued; wrought on one side and edges shot; wrought on both sides and edges shot; wrought on both sides, ploughed and tongued; boards keyed and clamped; mortise clamped; mortise and mitre clamped. The price per foot is also increased according to the thickness of the stuff. If the longitudinal joints are glued, so much more is added to the foot: and if feather-tongued still more.

Floors.—Are measured by the square, the price depending upon the surface, whether wrought or plain, and the manner of the longitudinal and heading joints, as well as upon the thickness of stuff; or whether the boards are laid one after the other, or folded; or whether the floor be laid with boards, battens, or wainscot.

Skirtings are also measured by the foot super; the price depending upon the position, whether level, raking, or ramping; or upon the manner of finishing, whether plain, torus, rebated, scribed to floor, or to steps; or upon the plan, whether straight or circular.

The price of every kind of framing depends upon the thickness, or whether the framing be plain or moulded; and if moulded, what kind of mouldings, and whether stuck on the solid, or laid in; whether mitred or scribed; and upon the number of panels in a height and breadth; also upon the nature of the plan.

The various descriptions of wainscoting, window-linings, as backs and elbows, door-linings, jambs and soffits, back-lining partitions, doors, shutters, are all measured by the foot super.

Sashes are measured by the foot super, as well as the sash-frames. The sash and frame are either measured together or separately.

Sky-lights are measured by the foot super, their price depending upon the plan and elevation.

Framed grounds, at per foot run.

Ledged-doors by the foot super.

Dado is measured by the foot super; the price depends upon the plan being straight or circular, or upon the elevation being level or inclined as in staircases.

In staircasing, the risers, treads, carriages, and brackets, are generally classed together, and measured by the foot super; sometimes the string-board is also included. The price must be different, as the steps are flyers or winders, or as the risers are mitred into the string-board, the treads dovetailed for balusters, and the nosings returned, or whether the bottom edges of the risers are tongued into the step. The curtail-step is generally valued as a whole. Returned nosings are sometimes valued at so much each, and if circular are double the price of straight ones.

The hand-rail is measured by the foot run; the price depending upon the materials and diameter of the well-hole, or whether ramped, swan-necked, level circular, or wreathed; or whether made out of the solid, or in thicknesses. The scroll is paid at per piece; as is the making and fixing of each joint screw; three inches of the straight part at each end of the wreath are included in the measurement.

Deal balusters are prepared and fixed at so much each; as likewise, iron balusters, iron column to curtail, housings to step and riser, common cut brackets, and brackets circular upon the plan, preparing and fixing.

Extra sinking in rail for iron balusters is charged by the foot run, the price depending on the rail being straight, circular, wreathed, or ramped.

The price of the string-board is regulated by the foot super, according to the manner in which it is moulded, or whether straight or wreathed, or the manner in which the wreath string is constructed, if properly backed upon a cylinder.

The shafts of columns are measured by the foot super, the price depending upon the diameter, or whether it be straight or curved on the side, and upon its being properly glued and blocked. If the column be fluted or reeded, the flutes or reeds are measured by the foot run, and their price depends upon the size of the flute or reed. The headings of flutes and reeds are so much each. Pilasters, straight or curved in the height, are measured in the same way, and the price taken per foot super. In the caps and bases of pilasters, besides the mouldings, the mitres must be so much each, according to the size.

Mouldings, such as double-faced architraves, base and surbase, or straight mouldings stuck by hand, are valued at per foot super. Base and surbase, and straight mouldings wrought by hand, are generally fixed at the same rate per foot, being something more than double-faced architraves. The head of an architrave in a circular wall is four times the price of the perpendicular parts, not only on account of the time required to form the mouldings to the circular plan, but on account of the greater difficulty of forming the mitres. All horizontal mouldings, circular upon the plan, are three or four times the price of those on a straight plan; being charged more as the radius of the circle is less. Housings to mouldings are valued at so much each, according to the size.

The price per foot super of mouldings is regulated by the number of quirks, for each of which an addition is made to the foot.

The price of mouldings depends also upon the materials of which they are made, or upon their running figure, whether raking or curved.

The following articles are measured by the foot run. Beads, fillets, bead or ogee capping, square angle staff rebated, beaded angle staff, inch ogee, inch quirk ogee, ovolo and bead, astragals or reeds on doors, or on shutters; small reeds, each in reeded mouldings stuck by hand up to half an inch, single cornice or architrave, grooved space to let in reeds, and grooves.

Note.—In grooving, the stops are paid over and above, and so much more must be allowed for all grooves wrought by hand, particularly in the parts adjoining the concourse of an angle; and circular grooving must be paid still more. The other running articles are, narrow grounds to skirting, the same rebated, or framed to chimneys; and rule-joints, cantalivers, trusses, and cut brackets for shelves, are rated at per piece.

Water-trunks are measured by the foot run, the rate depending upon the side of their square. These ought always to be properly pitched, and put together with white-lead, and the joints ploughed and tongued; the hopper-heads and shoes are valued at so much each; moulded weather-caps at so much each; the joints at so much each. Scaffolding, &c. used in fixing, to be paid for extra.

Flooring boards are prepared, that is, planed, gauged, and rebated to a thickness, at so much each, the price depending upon the length of each board: if more than 9 inches broad, the rate to be increased according to the additional width; each board listing at so much per list. Battens in the same way, but at a different rate.

Rates of Labour in Joiners' Work from the Bench, according to the universal Method described in pages 79 *and* 80 *of the First Volume of this Dictionary.*

The column on the left hand of the table denotes the number of panels, the middle column the species of work, and the right-hand column the rate in decimals, being the rate of the part or parts of a day required to the quantity signified at the head of the column; therefore, this rate being multiplied by the wages per day, gives the real rate of the work per foot, in shillings or pence, according as multiplied by shillings or pence.

DESCRIPTION OF ONE-AND-A-QUARTER INCH DOORS.

No. of Panels.		Rate per ft. super.
2.	Both sides square	.06
4.	Both sides square	.07
6.	Both sides square	.08
2.	Quirk, ovolo, and bead front, and square back	.1
4.	Quirk, ovolo, and bead front, and square back	.11
6.	Quirk, ovolo, and bead front, and square back	.12
2.	Bead and flush front, and square back	.1
4.	Bead and flush front, and square back	.11
6.	Bead and flush front, and square back	.12
2.	Bead and but front, and square back	.09
4.	Bead and but front, and square back	.10
6.	Bead and but front, and square back	.11
2.	Quirk, ovolo, and bead, on both sides	.14
4.	Quirk, ovolo, and bead, on both sides	.15
6.	Quirk, ovolo, and bead on both sides	.16
2.	Bead and but on both sides	.12
4.	Bead and but on both sides	.13
6.	Bead and but on both sides	.14
2.	Bead and flush on both sides	.14
4.	Bead and flush on both sides	.15
6.	Bead and flush on both sides	.16

For every additional quarter of an inch in thickness, add .005 to the rate per foot super.

If the panels are raised on one side, add .002; and if on both sides .004; and if an astragal or ovolo on the rising on one side, add .003; and if on both sides .006—to the rate per foot super.

If the price of a foot of a square door, and the number of pannels, are given, and the price of a foot of a door square on one side, with the same number of panels, and with extra work on the other side; then, the price of a door with the same number of panels, and the same extra work on both sides, will be found by subtracting the rate of the first from that of the second; and adding the difference to the second, will give the rate per foot extra on both sides.

Thus the rate per foot super for 1¼-inch two panel door, square on both sides, is .06; and the rate for 1¼ inch two panel door, square upon one side, with quirk, ovolo, and bead upon the other, is .1, their difference is .04, which added to .1, gives .14, for the rate per foot of 1¼-inch two panel, with ovolo and bead on both sides of the framing.

The difference of workmanship between square-framed door-linings, backs, elbows, soffits, or wainscoting and doors that are square on both sides, supposing the panels and thickness to be alike in both cases, can only arise from planing the panels and the framing on the other side of the door: therefore if the difference of the rate per foot of a door square on both sides, and one square on one side, with any extra work on the other, be added to the rate per foot of door-linings, backs, elbows, soffits, or wainscoting, framed square, will give the rate per foot for door-linings, window-linings, or wainscoting with the same extra work.

In these rates the styles or rails are supposed without rebating. Framed linings for walls or apertures, may be made of stuff ¼ of an inch thinner than doors. In common cases, the thickness of linings may be about an inch, as they are rendered sufficiently stiff by being fixed to the wall; this, however, must depend upon the distance that the panel recedes from the face of the framing, or upon the depth which the mouldings are run in the thickness of the said framing.

No. of panels.	Framed Inch Linings.	Rate per ft. super.
1.	Square, as in backs	.051
3.	Square, as in backs and elbows, measured together	.071
4.	Square, as in backs, elbows, and soffits	.061
3.	Moulded, as in backs and elbows, together	.087
4.	Moulded, as in backs, elbows, and soffits, measured together	.077
3.	Quirk moulded, as in backs and elbows, measured together	.095
4.	Quirk moulded, as in backs, elbows, and soffits, measured together	.085

Semicircular moulded soffits in two panels, seven times the straight.

For every additional quarter of an inch, add .005 to the foot super.

In the column of panels, the backs, elbows, and soffits, are numbered 3 and 4 panels, as being classed together; though this is the case, they are intended to be framed in single panels.

One-and-quarter Inch Door Linings,

Having only one panel in height.

Rebated	.051
Rebated and beaded	.058
Double rebated, not exceeding seven inches wide	.067
Double rebated, and one edge beaded	.071
Double rebated, and both edges beaded	.075

If the plan be circular, the price will vary as the diameter is less.

Semicircular heads, straight on the plan, five times the straight.

Shutters.	Rate per ft. super.
Inch framed, uncut, shutters or flaps, two panels in height. Mouldings, when described are understood to be laid in, but if stuck on the framing to add .012 to the rate; for every extra panel, to add .016 to the rate; for any extra height, to add .012 to the rate; if quirked moulded, add .008 to the rate of moulded.	
Square	.071
Bead, but, and square	.1
Bead, flush, and square	.111
Bead, flush, and bead but	.131

Inch-and-quarter uncut shutters, two panels in height, to add for extras, as above.

Moulded and square	.1
Moulded bead and but	.111
Moulded bead and flush	.135
Moulded on both sides	.111
Ovolo and bead, or quirk ogee front, and square back	.103
Ovolo and bead, or quirk ogee front, with bead and but back	.123

One-and-quarter Inch Wainscoting,

Two panels high, including square facia, framed up to ceiling.

Square	.039
Moulded	.055
Quirked moulded	.063
Bead and but	.051
Bead and flush	.059
Bead and flush, with 3 reeds	.075

If any of them are framed with raised mouldings, add .008 to the rate; or, if framed with more panels in the height, add .006 for every additional panel.

One-and-quarter Inch Dwarf Wainscoting,

With one panel, including square skirting.

Square	.047
Moulded	.063
Quirk moulded	.071
Bead and but	.059
Bead and flush	.067
Bead and flush with 3 reeds	.083

If any of the above descriptions of dwarf wainscoting are framed with two panels in height, add .016 to the rate, as in full wainscoting.

If made raking to stairs, to be paid for extra .023, and if with raised mouldings .007.

All cappings to be measured, and paid for as in running articles.

All skirting to stairs, to be paid for separate from wainscoting.

Three-quarter Inch Deal,

From the bench, called Slit Deal.

Edges shot	.004
Wrought on one side	.016
Wrought on one side, grooved, tongued, and beaded	.028
Wrought on two sides, and edges shot	.028
Wrought on two sides, grooved, tongued, and beaded	.04
If glued joints, add per foot	.004

Inch-and-quarter Deal.	Rate per ft. super.
Wrought on one side, and edges shot	.02
Wrought on two sides, and edges shot	.032
Wrought on one side ploughed and tongued	.036
Wrought on two sides, ploughed, tongued and beaded	.052

If glued joints, add .004 to the rate.

Inch-and-half Deal.	
Edges shot	.008
Ploughed and tongued	.024
Wrought on one side, with edges shot	.02
Wrought on both sides, with edges shot	.036
Wrought on both sides, ploughed and tongued	.052

If glued joints, add .012 to the rate.

Two-inch Deal,
From the bench.

Edges shot	.02
Ploughed and tongued	.036
Wrought on one side	.028
Wrought on both sides	.044
Wrought on both sides, ploughed and tongued	.056

If glued joints, add .016 to the rate.

Two-and-a-half-inch Deal,
From the bench.

Edges shot	.028
Ploughed and tongued	.048
Wrought on one side	.048
Wrought on both sides	.063
Wrought on both sides, ploughed and tongued	.083

If glued joints, add .016 to the rate.

Three-inch Deal.	
Edges shot	.032
Ploughed and tongued	.056
Wrought on one side	.056
Wrought on two sides	.08
Wrought on both sides, ploughed and tongued	.103

If glued joints, add .016 to the rate.

Inch Boarding, One Side planed.	
Ploughed and tongued	.024
Glued joint	.03
Clamped	.056
Mortise-clamped	.063
Laid with straight joint in floors	.02
Dado-keyed	.044
Keyed in backs and elbows	.056

Inch Boarding, wrought on Both Sides.	
Ploughed and tongued	.036
Glued joints	.04
Groove-clamped flaps to shutters, in one height	.053
Clamped flaps to shutters, in two heights	.071
Inch mortise-clamped outside shutters	.063
Ledged doors with plain joint	.044
Ledged doors, ploughed, tongued, and beaded	.056

Preparing Flooring Boards.

To be gauged to a width, and rebated to a thickness not more than nine inches wide.

Inch Deal.	Rate for each board.
Ten feet long	.063
Twelve feet long	.075
Fourteen feet long	.087

1½ Inch.	Rate for each board.
Ten feet	.071
Twelve feet	.083
Fourteen feet	.1

Battens 1½ inch.

Ten feet	.044
Twelve feet	.056
Fourteen feet	.075

Mouldings.	Rate per ft. super, from the bench.
Double-faced architraves	.111
Base or surbase	.127
Above four inches girt, stuck by hand	.127

If a collection of mouldings have more than two quirks, add .016 for each.

Running Articles.	Per foot lineal.
Beads and fillets	.004
Bead or ogee capping	.016
Inch ogee	.016
Inch quirked ogee or ovolo and bead	.023
Square angle-staff rebated	.028
Angle-staff rebated and beaded	.048
Single cornice or architrave	.048
Small reeds, in reeded mouldings stuck by hand, to half an inch	.004
Reeds above half an inch, stuck by hand, including grooved space	.008
Grooves in ornamental work	.004
Narrow ground to skirting	.011
Narrow ground to skirting, rebated or grooved	.016
Narrow grounds framed to chimneys	.032
Double-beaded chair-rail	.023

Plugging included in the above rates.
Such of the above running articles as are circular on the plan, must be rated at double the straight.

Legs, rails, and runners to dressers	.055
Rule-joints to shutters	.063

Inch and Inch-and-quarter Framed Grounds to Doors.

	Rate per run from the bench.
Both edges square	.028
One edge square, and the other rebated and beaded	.032
Rebated on one edge, and both edges beaded	.036

If framed to a circular plan with a flat sweep, the head to be three times the straight, but the less the radius the greater the price.

Stairs.

1¼ *inch nailed Steps with Carriages.*	Rate per ft. super fixed.
Flyers	.08
Winders	.111
Flyers moulded and glued with close string-board	.103
Winders moulded and glued with close string-board	.135
Moulded planceer under steps	.04

Housings to flyers, .127 each.
Housings to winders, .2 each.
Common cut brackets to flyers, .143 each.
Common cut brackets to winders, .286 each.
All fancy brackets to be paid for at per value.

HAND-RAIL.

2 inches deep by 2¼ inches broad	Rate per ft. run fixed.
Deal moulded	.111
Deal moulded and ramped	.495
Deal moulded, level circular	.413
Deal moulded wreathed	1.2
Mahogany moulded straight	.263
Mahogany moulded ramped	.831
Mahogany moulded swan-neck	.927
Mahogany moulded, level circular	1.08
Mahogany moulded wreath, from 12 inches and above	1.6
Mahogany moulded wreath, under 12 inches	1.8
Mahogany moulded wreath, not less than 12 inches opening	2.8
Mahogany moulded wreath, under 12 inches opening	3.4

Mahogany moulded cap, wrought by hand, .495 each.
Mahogany moulded cap, turned and mitred, .4 each.
Mahogany scroll, 1.8 each.
Making and fixing each joint with joint screw, .231.
Making model, and fixing iron balusters, each, 2.095.
Making model, and fixing iron columns to curtail, each, 2.142.
Preparing and fixing deal bar balusters, each, .04.
Preparing and fixing deal bar balusters dovetailed to steps, .056.
Extra sinking to rail, for iron rail or balusters 032
Extra sinking in ramp or wreath 1
Every half rail to be measured two-thirds of a whole.
All rails to be measured three inches beyond the springing of every wreath or circular part.
All cylinders used in rails glued up in thicknesses, to be paid for extra.

Articles rated at so much each.

Clamp mitres.
Cuttings to standards.
Housings in general.
Housings to steps.
Housings to mouldings.
Each scribe of skirtings to nosings of steps.
Elbow cappings.
Curtail step.
Returned moulded nosings to steps.
Caps to hand-rails.
Scroll of hand-rails.
Making and fixing joints of hand-rails with joint-screws.
Fixing iron columns in curtails of stairs and preparing mould.
Fixing iron balusters, and preparing mould.
Preparing and fixing deal balusters.
Brackets to stairs.
Mitres of pilasters according to their size.
Headings of flutes and reeds.
Hopper-heads to water-trunks.
Shoe to water-trunks.
Moulded weather caps to water-trunks.
Joints to water-trunks.
Preparing flooring-boards.
Preparing battens for floors.
Listing boards.

Articles rated at per foot lineal.

Sinking to shelves.
All raised panels on the extremity of the raising to be charged extra.
Moulded raisings of panels.
Coping to wainscoting.
Level circular string boards to stairs.
Hand-rails.
Newels to stairs.
Moulded planceer in stairs.
Sinking to rail for iron rail or balusters.
Pilasters under 4 inches wide.
Boxings to windows.
Water-trunks.
Skeleton grounds.
Flutings to columns.
Beads or fillets.
Bead or ogee capping.
Square angle-staff rebated.
Beaded angle-staff rebated.
Inch common ogee.
Inch quirk ogee.
Ovolo and bead.
Astragals on doors.
Reeds on doors.
Reeds on shutters.

Articles rated at per foot lineal.

Single cornice.
Single-faced architrave.
Ornamental grooving.
Narrow ground for skirting.
Narrow grounds for chimneys.
Legs, rails, and runners of dressers.
Rule-joints.
Framed grounds.
Skeleton grounds.

Articles rated at per foot super.

Planing, ploughing, tonguing, beading, gluing, and clamping deals.
Skirtings.
Sash-frames.
Sashes.
Sashes and sash-frames.
Sky-lights.
Framed back linings.
Back elbows and soffits.
Shutters.
Door linings.
Doors.
Wainscoting.
Partitions.
Dado.
Steps to stairs, including carriages.
Cradling.
Double-faced architraves.
Mouldings wrought by hand.
Shafts of columns.

Articles done by the square.

Laying floors.

Articles at per value.

Belection mouldings.
All fancy-works.

The English writers who have treated upon joinery, are, Moxon, in his *Mechanical Exercises*, second edition, printed 1693; Halfpenny, in his *Art of Sound Building*, small folio, 1725; Oakley, in his *Magazine of Architecture*, folio, 1730; Price, in his *British Carpenter*, quarto, 1735; Hoppus, in his *Builders' Repository*, quarto, 1738; Batty Langley, in his *Builders' Complete Assistant*, royal octavo, 1738; Salmon, in his *London Art of Building*, third edition, small quarto, 1748; Mr. Abraham Swan, in his *Architect*, folio, 1750; Pain, in almost every one of his works, particularly in *The Carpenters' and Joiners' Repository*, *The British Paladio*, *The Practical Builder*, and in *The Practical House Carpenter;* and the author of the *Architectural Dictionary*, in *The New Carpenters' Guide*, published in quarto, 1792; in *The Carpenters' and Joiners' Assistant*, quarto, 1792; in Rees's *Cyclopædia;* and in the *Mechanical Exercises*, octavo, 1812.

From these authors we shall here collect such extracts as relate to mechanical principles, or to geometrical construction, in the order of the above list.

Moxon treats the subject merely as a manual art. The following is extracted from Halfpenny's *Art of Sound Building:* he seems to have been the first writer who considered joinery in a geometrical point of view; his knowledge, however, is entirely confined to hand-railing.

"*To find the raking arch, or mould, for the hand-rail to a circular pair of stairs, in such a manner that it shall stand perpendicularly over its base, or arch of the well-hole.*

Figure 95.—"First describe a circle equal to the breadth of the well-hole, whose diameter is U W; as also another from the same centre, whose diameter is A G, to represent the plan of the rail; and divide the circumference of the greater circle into the same number of equal parts as you would have steps once round the circle.

"This being done, take the back, or rake, of the bracket, equal to C F, in your compasses, and setting one foot in A, with the other strike the arch *h:* also take the height of one step, as A C, *Figure* 96, and setting one foot in B, with the other strike the arch *i;* and when this is done, take the distance from A to *h* in your compasses, and setting one foot in *h*, with the other strike the arch *k*, and take the height of two steps, and with one foot in C, draw the arch *l*, to intersect the arch *k*, and so on.

'The intersecting points of the arches *h i*, and *k l*, and *n o*, and *r s*, and *t u*, are all at the same distance from one another, and the lines B *h*, C *k*, D *n*, E *p*, F *r*, and G *t*, being the risings or heights of the steps, in *Figure* 96, B *h* being the height of one step, C *k* of two, D *n* of three, E *p* of four, F *r* of five, and G *t* of six. Now, if these lines are raised up perpendicular on the circle A D G, it is evident that the point of intersection of the arches *h* and *i*, will stand perpendicularly over the point B; of the arches *k*, *l*, over C; of the arches *n* and *o*, over D; of the arches *p*, *g*, over E; of the arches *r* and *s*, over F; and of the arches *t* and *u*, over G. Now, if nails be struck into the intersecting points of the said arches, and a thin rule be bent round them, you may describe the arch, A *h k n p r t*, by the edge thereof, being the mould to strike the arch of the rail with.

"*The arch or mould of the rail being found, as above, how to prepare the stuff of which the rail is to be made, and work the twist thereof without setting it up in its due position.*"

Figure 97. "First strike two circles, whose diameters are equal to U W and A G, in *Figure* 95, and next consider into how many pieces you glue the rail, which in the semicircle let be six, as in the example.

"Now divide the semicircle into six equal parts, as E F, F M, M S, S L, L D, and D K; from each of these points of division, draw lines to the centre A, as A E, A F, A M, A S, A L, A D, and A K. Then from F raise F G perpendicular to A F, and equal to the height of one step. Also, at the point M, raise M N perpendicular to A M, equal to the height of two steps; and in like manner at the points S, L, D, and R, raise the perpendiculars S T, L Y, D E, and R L, respectively equal in length to the height of three, four, five, and six steps. Then draw a line from G to R, parallel and equal to A F; as also another from N to *y*, parallel and equal to A M; another from T to W, parallel and equal to S A; another from Y to B, parallel and equal to L A; another from E to H, parallel and equal to D A; and another from L to P, parallel and equal to K A. From the point A draw the line A B, perpendicular to A E, and equal to the height of one step; also at the points R *y*, W, B, H, P, draw the lines R L, Y Z, W X, B C, H I, P O, all equal to the height of one step, and respectively perpendicular to R G, Y N, T W, Y B, E H, L P, and draw the hypothenuse E B, L G, Z N, T X, Y C, E I, L O.

"This being done, set off the width of the rail from E to *d*, G to *i*, N to *o*, T to *u*, Y to *a*, E to F, and L to *m*; and set the stem of a square on the line E B, till the blade touches the point *d*, and draw the line *c d*. Moreover, set a square on the line G L, and where it cuts the line R G, as in the point I, draw the line *h* I; and in like manner draw the lines *p o*, U N, Z *a*, *g* F, and *n m*. Then the angles E *d c*, G I *h*, N *p o*, &c. and the rest of the little black spaces, as you see in the Figure, do represent the twisting of each piece, and what must be taken off from the back at the lower end, to make the twist of the rails. The lines being drawn, you are next to consider after what manner they are to be applied in the working of the rail.

"Take the piece of timber, of which you design to make the first length, which is represented in *Figure* 98, and plane one side thereof straight, and cut it to its bevels *a c*, *b d*, answering to D R A and R D A, *Figure* 97, and both ends thereof being also cut to the raking-joint of the rail, proceed thus: Take that part of the raking-arch in *Figure* 95, which answers to the first length of the rail, as A *h* in the arch A *u*, and lay it on the upper side of *Figure* 98, from *l* to *h*, and strike the arch *l h*, then take E *c*, equal to G *h*, or N *p*, in *Figure* 97, and set it on the line *b d* from *h* to *m*, *Figure* 98, and strike a square stroke at pleasure from *m* to *g*; also take *d* equal to *h* I, or *p o*, &c., *Figure* 97, and set it on the line from *m* to *g*, and draw the line *h g*, which represents the back of the rail when it is worked, and is equal to E *d*, or G *i* or N *o*, &c., *Figure* 97. This being done, represent the lower end of the rail *h g k i* at right angles to *h g*; as also the upper end *l c o n* at right angles to *l c*, and baste out the inward arch *c m* square from the upper side *a b c d*, as *m g*; and take a thin lath, and bend it close to the side thereof, from *c* to *g*, whereon strike a line along the edge of the lath, and so the lines *l h* and *c g* are your guides in backing the rail; which, when done, turn the piece upside-down, and with the mould strike an arch equal to *l h*, from *a* to *k*, and baste out the side to the lines *l h* and *o k*; then you have one side and the back squared, which is the greatest difficulty in the formation of a twisted rail, because the two other sides are found by gauging from them.

"*Note.*—If the triangles in Figure 97, and lines whereon they stand, be supposed to be raised up perpendicularly, then will the lines A B, R L, Y Z, W X, B C, H I, and P O, join to each other, and produce one line perpendicularly over A, equal to seven risings or heights of the steps. But in working a rail of this kind, you have need of but one triangle, A B C E *d*, because they are all equal, and of but one effect in working, they being drawn only to satisfy the curious in the nature of the thing."

He finds the moulds for elliptical staircases in a similar manner, viz., by finding an arch line divided into equal parts, so that each of them may be equal to the hypothenuse of the pitch-board, and the distance of the points of division in succession respectively equal to the heights of the steps: this principle is to be understood in all staircases where the steps are equally divided at the well-hole, whatever be the form of the plan: but in elliptic staircases the degree of twist is different, and therefore requires a pitch-board to be made for every portion.

It is hardly possible to conceive any method so distant from principle as what is here shown: the squaring of the wreath is altogether guessed at, not to mention the great disadvantage in making the rail in so many pieces. If the rail were really executed, the above method would then be a property; but the moulds never can be obtained from any construction in plano upon the same consideration. It is rather astonishing that any attempt should be made at demonstration, for the support of a method so entirely destitute of principle as the above.

"*How to form the arch or mould to the hand-rail of a pair of stairs that sweeps two steps, so as to stand perpendicularly over its ground, and the manner of squaring the same, without setting it up in its position.*

"First: draw *Figure* 99, to represent the ground-work of the rail, whose arch, G C, consists of two different arches, one whereof is a quarter of a circle, the other a quarter of an oval. A B (equal to A C, equal to C D, equal to B D) is equal to one-third of a step: and D is the centre to the arch C B; also, B F is equal to two-thirds of a step, and F G is equal to one step and two-thirds; by means of which, and B F, is the arch G B described. G K represents the straight part of the rail to one step, and the arch H D is drawn by gauging from the arch G C; that is, it is drawn parallel to it, and the straight part I H is found by gauging from K G, or is drawn parallel to it.

Figure 100, "shows the manner of drawing the rake or arch of the rail, which is done thus: draw I L equal to G K of *Figure* 99, and represent the tread of the steps as before, by pricked lines. Then divide that part of the ground-work of the rail which belongs to each step into any number of equal parts, as A F into five, and F K into four. This being done, draw A B, B C, C D, in *Figure* 101, to represent the

rising and tread of the steps, and continue out the line C B at pleasure, towards T, in which set the five divisions on the ground of the rail to the first step F E, of *Figure* 100, being equal to C *i* of *Figure* 101; also, E D equal to *i k*, D C to *k l*, C B to *l u*, and B A to *u* T. Then will the line C T, in *Figure* 101, be equal to the arch A F, of *Figure* 100; draw the line D T; then is the triangle C D T the bracket to the first step, according to the sweep of the rail: and as T C is the length of the ground to the first step, so is T D the length of the rail answering to it. Then from the points *i*, *k*, *l*, *u*, raise the perpendiculars *i* P, *k* Q, *l* Z, and *u* S, to C T; and take the four divisions on the second step, and set them in the line C T, from C to B, and draw the line B D; and then is B C the length of the ground to the second step, and B D the length of the rail answering to it. Draw lines through these divisions, as from F to *m*, G to *n*, and H to O, perpendicular to C B; and so your perpendiculars are found according to the compass brackets of each step, and may be pieced thus:—

"In *Figure* 101, take T S in your compasses, and with that distance, setting one foot in A, in *Figure* 100, strike the arch *m*; and take S *u* between your compasses, and with one foot in B strike another arch to intersect the arch *m*. Again: take S Z or S T in your compasses, and with one foot in the intersection of the arch *m* and this latter arch, describe the arch *n*; and take *l* Z in your compasses, and with one foot in C describe an arch to intersect the arch *n*; and thus proceed on, so that Z Q be equal to *n o*, Q P to *o p*, P D to *p q*, *q z* to B *o*, *z s* to *o n*, *s t* to *n m*, and *t u* to *m* D; as also *k* Q to D *o*, *i* P to E *p*, C D to *q* F, H *o* to G *z*, G *n* to H S, F *m* to I *t*, E D to K *u*, L *w* to three times A B. The points *n*, *o*, *p*, *q*, *r*, *s*, *t*, *u*, *v*, *w*, being found by the intersection of arches, as above, stick a nail into each point, and bend a thin rule about the nails, till it touches them all, then with a pencil describe an arch round the edge thereof, which will be the arch A *w*, being that of the rail to work by.

"*Figure* 102 shows the manner of squaring the rail, which is thus: first, describe A F, the square, or ground of the rail, being the same as that of *Figure* 99, and find the centres to answer to the different arches of the ground; from whence draw pricked lines to the places where you design to join the rail, as from G to B, from G to C, from H to E, and from H to *d*. Because the first step is to be joined in three equal pieces, you must take one-third of the rising or height of the step, and set it from B to I, perpendicular to B G, and draw the line M I, parallel and equal to G B. Now, from M to *n* draw a perpendicular to M I, to rise so much as the rail rakes over, which is one-third of the rising or height of the step, because that part of the rail is one-third of the length on the first step; and draw the line I *n*, by which means we shall have the first triangle I M *n*. Then from the point C, draw C *q* perpendicular to G C, and equal to two-thirds of the height of one step; and draw the line *q z* equal and parallel to C G; and from *z* raise a perpendicular, *z s*, to *z q*, equal to one-third of the height of one step, and draw the line *q s*, and you will have a second triangle. Again, from *d* draw *d* T perpendicular to H *d*, and equal to the height of one step, and draw the line T W equal and parallel to H *d*; and from W erect the line W X perpendicular to W T, and equal to the height of one step, because that part of the rail over the second step will be one piece, therefore the triangle must rise one height of the step; and draw the line T X, and so you will have a third triangle, W X T. This being done, from I in the line I M, set off I *k*, equal to the width of the rail; also set off the same from *q* to *o*, and T to *u*, and setting the stem of a square on the hypothenusal line, so that the blade thereof touches the point *k*, draw the line *k l*; and in like manner draw the lines *p o*, *u v*; and then the little triangles I *k l*, *q o p*, T *u v*, do represent what must be taken off from the lower end of each piece, to bring the rail to its true twist."

The form of the scroll is only a subject of fancy, but what has been quoted from this author, will show the difference of taste between the time when such were in use, and those of the present day. No elegant geometrical forms seem then to have been employed. As to the construction of the raking-mould for the scroll, it is done in a similar manner to the twist of the rail, before shown, and therefore equally destitute of principle.

Mr. Edward Oakley, in his *Magazine of Architecture*, has copied Halfpenny's descriptions and diagrams; to which we refer the reader.

The next work under review is *The British Carpenter*, by Francis Price. The article Joinery is almost confined to hand-railing, as in the preceding authors. Mr. Price proceeds as follows:

"*To find the proper kneeling and ramp of rails.*—In *Figure* 103 is represented a short flight of four steps, and part of a half-pace, on which are shown two balusters on a step; *a b* is the rise or height of one step, and *b c* is the newel, generally two feet four inches and a half high, and sometimes two feet six inches high, &c., and *c d* is the thickness of the rail; the kneeling, *o*, is in the middle of the first baluster; from *e* to *f* is also the height of the first step on the half-pace; and *f g* the height of the newel, agreeable to that of *b c*; and *g h* is the thickness of the rail; from *h* to *i* is generally the same as from *o* to *c*, which line, *h i*, continue at pleasure; for on it is the centre for the ramp. With your compasses find the centre, *k*, which touches the back of the rail, *n*, and the point of the ramp, *i*; find the point of touch, *n*; draw the line *k n*; describe the ramp, and also the turned part of the balusters, as may be seen by the pricked line.

"Over this is represented the alteration that ought to be made, if you place three balusters on a step; that is, that the kneeling ought to come to the back-side of the first and last balusters, as at *p* and *q*. If it be said, the method in *Figure* 103 is not fully expressed; to find the height of the ramp agreeable to the kneeling, let *Figure* 104 be the rail, the bottom is continued as by the pricked line appears at *u* and *w*; take the distance, *u t*, and set from *w* to *x*; from *x* set one rise, or the height of one step, as at *y*, and that gives the height of the ramp, and is the same as the method in *Figure* 103, notwithstanding they differ in appearance.

"In *Figure* 105 is shown the manner of fluting newels for stairs, and balusters; the newel having twelve flutes, and the balusters eight. If the stuff be large, the flutes may vary; thus the newels to have sixteen flutes, the balusters twelve."

We cannot comment any farther on the above, than that it shows the method of describing the ramp of a rail, and the difference of taste in the age of Price, from that now in use. The design, the quantity of work, and the massy parts, which characterized that time, when contrasted with the slightness and plainness of work executed in the present day, are really astonishing. Our hand-rails are very light, but very neat; when ornamental work is used, it is chiefly confined to iron, being rarely constructed in wood.

"Whatever may appear difficult in this method of forming scrolls proper for the plans of twisted rails, due application will make easy and expeditious.

"First, form a scroll with chalk, or a pencil, agreeable to the bigness of the place in which it is to stand; next resolve on the bigness of your stuff to be used for your rails, and also your mouldings on the side thereof, as in *Figure* 106

Let *d* be the centre of your chalked scroll in *Figure* 107; on which describe with the projection of your mouldings from *Figure* 106, the small circle *d;* take from *Figure* 106, half the bigness of the stuff, as *e g*, or *e f*, which add to the small circle, and form the circle *h i t*, which is the bigness of the eye of the scroll: this done, take the distance from *i*, to the inside of the rail, as the supposed chalked scroll, which suppose *k;* with it, make a diminishing scale, by setting that distance up, from *t* to *l;* draw the line *k l;* place one foot of your compasses in *k*, describe the part of a circle *t* 8, which divide into eight equal parts, because here your supposed chalked scroll was to come into its eye, or block, at one revolution of a circle. (Scrolls may be made to any number of revolutions desired, by the same rule, witness that above, in *Figure* 108.)

"Place one foot of your compasses in *d*, describe the large circle *w l l u*, which always divide into eight parts, because you strike one eighth part of a circle every time, till you come into the eye, or block, *i t h;* from the said divisions on the large circle, draw lines through, for on them your sections meet, which form the scroll. It is observable in drawing your sections, that they do not end in the line drawn through the great circle, only the outside scroll; for those of the inside scroll end on a line drawn to each respective centre. I suppose A and B to be two steps; the rest, I think cannot fail of being understood, by observing the letters and figures, which show each part distinctly."

Mr. Price's advice, to make a scroll first of chalk, is altogether ungeometrical, and therefore unworthy of notice. The method of forming it is of Italian invention. A similar construction is used in describing the Ionic volute in Daviler's *Cours d'Architecture*, dated Paris, 1720. He ascribes the invention to Vignola. But, in our opinion, it is far from producing that agreeable variation of curvature required. The opening next to the eye expands too rapidly towards the extremes. A much more perfect method, and not very dissimilar in construction, is that published in the *Joiner's Assistant*, by Nicholson. *See* the Articles SPIRAL and SCROLL.

"In order to make the squaring of a twisted-rail easy, see the plan, *Figure* 109, which is the same as that in the foregoing *Figure* 107, and find the point of touch, *b*. From these curves a mould must be traced out, in order to form a sweep, which when applied on the rake, is agreeable to this of *a b*, *c d*, as that of *Figure* 110. (It is first to be observed, that you will want wood extraordinary, both on the top of the rail, as in *Figure* 111, at *e*, *a;* and also under the same, as *g*, *h*.) To find which, observe where your sweep begins, in the plan *Figure* 109, as at *a c;* also observe that *o* and *n* is the end of the twisted part. Therefore, from *a* to *n*, divide into a number of equal parts, so as to transfer them on some line, as in 112, from *a* to *n;* also divide the inside of 109, as from *c* to *o*, into equal parts, so as to transfer them on some line, as in 113, from *c* to *o;* take the distance *e a*, in 109; apply it to the pitch-board, as from *g* to *e;* take the pitch-board, 114, with its place *e* to *c*, in 113; draw the line *d g*, and make the point *s;* divide from *d* to *s* into eight equal parts, also from *d* to *o* into the same number; draw the lines, which form a sweep, whose use shall be hereafter shown.

"Likewise take the pitch-board 114, and apply *e* to *a*, in 112; draw the line *e p*, and make the point *r;* from *e* to *r* divide into eight equal parts; also from *e* to *n* do likewise; draw straight lines from each division; that curve shows how much wood is wanting on the back of the rail, as *b t*, which describe in 111, from *e* to *a;* and there describe the bigness of the rail; which shows how much wood is wanting, as may be observed by what was said above. The other part of the twist is cut out of a parallel piece, as 115; which thickness extraordinary is shown in 111, at *e a*.

"To square the twisted part of the rail, having so much wood extraordinary on the top and bottom, observe in 109, from *a* to *e*, and from *c* to *f*, must be traced as was above mentioned. Take *a e* in 109, apply it to the pitch-board 114, it shows *g i*, which length place in 110, from *k* to *i;* also, take from 109 the distance *b d*, apply it to the pitch-board 114, it shows *g m*, which length place in 110, from *l* to *m*. This done, trace out the raking-mould 110, agreeable to the plan 109, which, by inspection and a little practice, will become easy, and without which nothing is known truly. I say, the wood extraordinary being accounted for in 111 both on the top and the bottom of the rail, observe to place your stroke *f* in its true place, that is, at the beginning of the twisted part; take the raking-mould 110, set *i* to *f* in 111; there strike it by; with the angle of your pitch-board describe the pricked line *f*, by the side of the rail; then apply the mould 110 to the bottom; set *i* to this pricked line, and there describe by it, with your pencil. Lastly, cut that wood away; also, cut the remaining part of the scroll out of the block; as 115; then glue these together, and bend both moulds, 112 and 113, round the rail; strike them by that, and cut the wood away; so will the back of your rail be exactly square, and fit to work."

This method of squaring the twist of the scroll is correct; the principle is that of the section of a curved prism at right angles to a given plane, and amounts to no more than tracing a common angle-bracket. The construction, however, requires a very considerable addition to the thickness of stuff; and even this thickness will be variable, according to the place of the pitch-board. This method, though much superior to that of Halfpenny, is not to be compared with that of springing the plank, introduced by Mr. Nicholson.

Mr. Price says, that his method will apply to any twist or wreath whatever: we grant that it will; but then the stuff would require to be from 4 to 8 inches in thickness, and sometimes more. In drawing the section upon the plank, in order to be cut out, the shank of the mould is always applied parallel to the arrises; this application occasions also a great waste in the breadth as well as in the thickness. In the construction of the face-mould of the scroll, he employs the pitch-board of the flyers. He gives no example of forming a wreath over winders; but if the same principle is to be applied, recourse must be had to a development of the steps. It is unnecessary to make any farther observations, as the author of the Architectural Dictionary, Mr. Nicholson, has placed these and his own before his readers, in order to compare and point out the specific differences of each, by proper diagrams, at the end of this article.

"You are always to observe this general rule, viz., to conceive each respective paragraph, as it occurs, before you begin another; the neglect of which appears by some who cannot conceive the particulars of the foregoing Figure, although I had put it in so clear a light.

"I have here described three distinct methods of squaring the twisted part of a rail, which may be known, and the rail squared, with more ease than in the foregoing Figure. But when done, they will not have that agreeable turn in their twisted part as they would have, if done by the foregoing unerring rule, as may more clearly appear by the following explanation:—

"That of *Figure* 116, is the raking-mould, taken from *Figure* 110 (whose use and application was therein clearly shown); that of 117, is the pitch-board, taken from 114; which gives the rake or declivity of the rail.

"In *Figure* 118 is shown how to square a rail, without

bending a templet round the twisted part thereof; and which is by being guided by the back; first, describe the bigness of the stuff to be used, as *a b h i*, which shows how much wood will be wanted at bottom, supposing s to be the side of the rail. And because the grain of the wood should be agreeable to the falling of the twist, therefore consider how many thicknesses of stuff will make the wood required to cut the twist out of; as here three. Therefore, as in s, continue the line *a b*; place one foot of your compasses in *a*, make the section, or part of a circle, *c d*; divide it into four parts, as 1, 2, 3, 4, because the rail s must be always reckoned as one; this, by inspection, shows how the grain of the wood is to be managed, as appears by the shape of the several pieces, 119, 120, 121, which are better, if cut so by the pitch-board, before glued together.

"In 122 is shown how to square the twisted part, making the bottom your guide; the section shows how much wood is wanted on the back.

"In 123 is shown how to square the twisted part, making a middle line on the back your guide; the section shows the wood wanting on the back and at the bottom.

"That of 124 may be cut out of a parallel piece, of the thickness of the intended rail, which, when it is glued to the twisted part, will want little or no humouring.

"*N.B.*—There is a nicety in working the mitre thereof, as *k l m*."

The above method of forming the wreath by gluing different thicknesses together in parallel blocks, perhaps originated with Price, or might be in use among workmen in his time. The process is quite mechanical, and what might occur to any well-informed workman. And though the wreath might be got out of much less stuff than by the former principle, it is tedious, and much more uncertain. To apply these properly would require the workman to understand the method of orthographical elevations; and though Mr. Price seems to have had a notion of this, his representations of the wreaths are all drawn by guess, and are therefore not to be depended upon. Another method by which this might have been ascertained, is by a plan and development of the twist, where the risings of the blocks might have been ascertained according to their several thicknesses; we shall show this improvement at the end of this article, accompanied with a diagram.

"You are to observe, the foregoing Figures must be well understood; and then, in these Figures the lengths of the newel and balusters that stand under the twist or scroll are truly described; that is, their lengths and bevels may be known before the rail be put up in its place; and, that it may prove easy, observe the plan, *Figure* 125, of the twist or scroll is the same as before, and so are the two steps P and Q, and the pitch-board, 126.

"First, resolve on the bigness of your balusters, as *a*, *b*, *c*, *d*, *e*, *f*, and also the newel. Divide the said balusters truly on a line drawn in the middle of the rail; for then what is wide on one side is narrow on the other. It is for that reason I choose to divide them on a middle line. Describe the plan of the balusters, as *p q*, *r s*, *t u*, *u w*, *x y*, and *z*, for there your twisted part ends; from thence to the eye is level.

"Observe where your scroll begins, as at *l*, and on some line, as above in 127, first make a point at *l*; then from your plan take the distances *p q*, *r s*, *t v*, *u w*, *x y*, and *z*, which transfer as above, observing to have regard to place truly each distance from *l* both ways, as *p q*, *r s*, *t v*, *u w*, *x y*, and *z*. Observe also to take from the plan the distance from *l* to *m*, which apply to the pitch-board R, as from *h* to *n*, which gives the length *h o*; take this pitch board and apply it on the line above, which, by inspection, the letters will show; this gives the slope of the rail, as *h o &c.* From *o* to *h*, and from *h* to *y*, form the curve by equal divisions, and drawing straight lines, as was before shown.

"Lastly, having the lengths of your fixed balusters, as *a b*, *Figure* 127, describe the steps s and T with the pitch-board: so that by continuing perpendicular lines, from the points on the line first terminated to the said curve and to the steps, you have the accurate lengths of the balusters, as *a*, *b*, *c*, *d*, *e*, *f*; the newel *g* being the same length as *f*, because at *f* or *z* the twisted part ends.

"The curve of the first, or curtail-step, *Figure* 125, is formed by the same rule as delivered for the plan of the rail.

"It may not be amiss to observe particularly the point of the sweep or curve's beginning, and being particular also in its application, by which this and the foregoing, though represented with but two steps, is the same, in fact, as though I had described a whole flight to show its use."

To ascertain the height of the balusters is not of very great importance to workmen of the present day. The method is, however, correct; and though it might be laid down and expressed more clearly, it is as eligible as any that can be applied to the purpose. Price's remark for taking the middle line for the division of the balusters is judicious.

"Zealous to promote," says he, "what may be useful, I have made easy the difficulty of squaring a rail that ramps on a circular base.

"Observe, *Figure* 128 is the plan of a staircase; and at the landing is a quarter-circle: to make this easy, in 129, is three steps, described by a larger scale, and the same method as shown in 103, 104. Likewise, 109 is the plan of the rail. It was shown in 110, &c., how to trace out a mould on the rake, agreeable to this plan, or indeed any other. A considerable thickness of wood more than usual is required on the back of this rail, which will appear more plainly by inspecting 117, &c., as also the method to trace your moulds that shall bend round the said rail. Let the sides be squared, as was shown in 109, 110, 111, 112, 113, 114, 115. Observe here, in *Figure* 129, the line *k p o*; take the distance *k p*, and place it on some line at pleasure, as in 130: then divide the outer circle in 130 into a number of equal parts, as into six, as from *g* to *h*, which transfer to 131, as *g*, 1, 2, 3, 4 5, 6, *h*. The point of the ramp may be observed to fall within the fifth division, at *s*; so that by the intersection of straight lines and equal divisions, you describe the sweep for the ramp *g b*, which makes 131, the mould, to bend round the outside of the said rail.

"Observe also in 130, from *e* to *f*, divide it into six equal parts, which transfer to 132, as from *e* to *f*; and (observe again) the ramp falls within the fifth division, as at *r*. So divide the distance from *e* to *g*, and from *g* to *b*, into equal parts, and by drawing straight lines, you have the sweep *b e*. From the point *b*, to *p*, is the thickness you want to be added extraordinary on the back of the rail 132, and which is the inner mould; so that by bending both these moulds round the rail, and by drawing them with a pencil, and cutting away the superfluous wood, you have an exact square back.

"There seems no difficulty now left unmentioned, to square twisted rails in any form whatever.

"Because I have all along strove to give variety, observe 133, in which is shown a method to have your newel under the twist, the same length as the rest; by which means also the rail twists no farther than the first quarter, and consequently the remaining part may be cut out of a plank, of the thickness of your rail, without twisting at all. There seems no explanation wanting to clear this point, but inspection and a good conception of *Figures* 109, 110, 111, 112, 113,

114, 115: in this of 133, *l f* is the thickness of wood extraordinary wanting on the back of the rail."

The method which Mr. Price employs at 132, for ascertaining the thickness of stuff by a falling-mould, or development of the side of the rail, is incorrect; nor can it be found in a determinate manner without an orthographical elevation of the part of the wreath to be formed. This concludes the whole substance advanced by Price in the article Joinery, and shows improvement only in its infancy.

Mr. Price has also shown the method of forming raking-mouldings for pediments, as follows:

"And in consideration that no pediment can be performed without two kinds of cornice, (except it be knee'd at its bottom or springing, which is reckoned a kind of defect,) therefore to give each of the cymas such a shape, or curve, as shall strictly agree in their mitre, do thus: Describe the curve of the level cornice F, *Figure* 134, as *a b c*, by two such portions of circles, as that the centres for forming each may be on a horizontal or level line, drawn through the middle of the said cyma; as * *, *c d*; being the projecture thereof. Draw lines from the points of the said cyma, agreeable to the slope of the pediment, which gives or terminates the bigness of the raking cornice or cyma G; so that by drawing a line through the middle of the said member, on it are the centres * *, by which the curves *e f g* are described; the projecture. *h g*, being as before. In case a break or return be made in the pediment, then another kind of cyma must be formed, which shall agree with the two former, as H; the centres for forming each curve being on an horizontal line drawn through the middle of the cyma, as before; *i k l* is the curve, whose projecture, as before, is *l m*. These three kinds of cornice being thus formed, will agree with each other, without the trouble of tracing. But if the given curve be not described as before, then observe the method proposed in 135; by which the curve of any raking-mould whatever may be truly described. Admit the cornice given were K; *n o p* being its curve, and *p q* its projecture; by making points on the said curve, draw lines from them, agreeable to the slope of the pediment, on which place each respective projecture from K to L, so is *r s t* its curve, the projecture being *t u*, as before. And if a break or return be made, as M, then transfer the several projectures from K, observing that the points be on the lines drawn agreeable to the rake of the pediment, so will *w x y* be the curve, and *y z* the projecture, as before: which no doubt but inspection explains."

The scheme for raking-mouldings, shown at 134, is not to be depended upon. It is evident that since the figure is a prism, and since the given curve is composed of circles, the curves required must be composed of elliptic segments, unless the sections are parallel to each other, which is not the case.

The second method, shown at 135, is perfect, and is the first thing of the kind that is to be found in any English publication.

We come now to the *London Art of Building*, by William Salmon; and as it is our province to repeat only the inventions and improvements in joinery, we shall therefore omit what Mr. Salmon has said on the formation of the scroll; being, in method and substance, the same as that which we have detailed from Mr. Price, who certainly gave the first rational method of squaring the twist for the scroll part of the rail, either from his own invention, or from a practice known among workmen. And as Mr. Price has only shown the formation of the twist of a scroll, and of a rail upon a quadrantal plan in a level landing, we shall here detail the application made of the same principle by Salmon to a winding stair, where the treads of the steps are all equally divided around the circumference; but first it would be necessary to notice the candid acknowledgement which Mr. Salmon has made in respect to the principle.

"I must confess, for this method of forming twist rails, I have had my eye upon, and am obliged to, my ingenious friend, Mr. Francis Price, in his *Treatise on Carpentry*, lately published; though, on comparing them, you will not find them alike. This method of forming the raking-mould will serve for all twist rails whatsoever, with due application, as shall be shown in another example of a staircase, having a circular well-hole.

"*Figure* 136, is the plan of a circular rail having sixteen steps in the whole circumference; but here it is proposed to find the raking-mould to a fourth part thereof, or four steps, it being to a small scale. The plan being laid down, as *a c d e*, *Figure* 136, divide the outer circle into a number of equal parts, so as to transfer them on some line, as *a c*, *Figure* 137; and setting up the rise of four steps, as *a b*, gives the pitch-board, due to them all. Then taking *b c*, in *Figure* 136, applied to the pitch-board, *Figure* 137, from *c* to *d*, it gives *c e*, which transfer to *Figure* 138, from *b* to *c*. Also, from *Figure* 136, take *a d*, placed in *Figure* 137, from *c* to *g*, gives *c f*, which transfer to *Figure* 138, from *a* to *d*; and there tracing, as before taught, you will form the raking-mould required."

In such a staircase as the above, the waste of stuff is great, but when does it ever come into practice, that the steps are equally divided? In every stair there must be a landing and this would require much thicker stuff: Again, if the stair is mixed with flyers and winders, the waste stuff would in many cases be enormous, and still more so, if the joint were brought over the flyers, in order to secure the wreath and straight parts more firmly by a screw, as is the case in modern practice. The greater number of stairs now in use, are constructed upon this plan.

"Some able workmen have another method of forming this rail.

"First, they make a cylinder, equal to the whole well-hole, *f*, *e*, in *Figure* 136, or part thereof, either solid (if the well-hole be small) or (if large) by fastening boards together upright, in the exact form of the plan.

"Then they proceed to set on the said cylinder, as *Figure* 139, the height and breadth of each step, as *a*, *b*, *c*, *d*, *e*, *f*, &c., and to the extreme points, *b*, *d*, *f*, they bend round several thin pieces of the breadth of *c*, *f*, in *Figure* 137, and being glued, or otherwise fastened together, till they make the thickness of the rail, I say these when taken off from the cylinder, will be the rail, and exactly squared to the right twist.

"This is a very safe and sure method, though not very frequently made use of.

"Either of these ways will serve, should the well-hole be an ellipsis, or any other figure for its plan."

The first idea of gluing a rail in thicknesses is here shown, but the description, and the figures accompanying it, are very imperfect; nor will the rail come off squared, as Mr. Salmon asserts, without the veneers are all different in proportion to the radius of their plan, except, indeed, upon the plan which he has shown, where the rail is supposed to be continued, and therefore requires much amendment to be brought into general use.

Langley's improvements are as follow

"*To describe a twisted rail.*—Let the lines B D E, *Figure* 140, represent the edges of the two lower stairs of a staircase.

"Divide *b* 9, the tread of the second stair, into nine equal parts, continue the line D towards the left at pleasure. Draw N F, parallel to 9 *b*, at the distance of seven parts also

draw the line 14 *d* at the distance of three parts, then *d b* is the breadth of the hand-rail. Draw A *n* parallel to 9 *b*, at the distance of *b* 9, then the point *n* is the centre of the eye of the scroll. On the point *a* describe the quadrants *b c* and *d e*, which is the length of the twisted part of the rail, the remaining part, to *n*, the eye, being level. On *n* describe the circle *z x p*, whose diameter, *w p*, must be equal to *d b*, the breadth of the hand-rail. Divide the radius, *n p*, into four equal parts, and through the first part, at *o*, draw the line *r l*, cutting the line N F in *x*: on *x* describe the quadrants *c f* and *e g*, make *o t* equal unto two parts of *n p*, and draw the line *t s* parallel to A *n*. On the point *t* describe the quadrants *f h* and *g z*, make *n w* equal to three parts of *n p*, and through the point *w* draw the line *z k*, parallel to *r x*; on *z* describe the quadrant *h v*, and on *w* the quadrant *v p*, and then is the plan completed."

This is a very anomalous attempt at the description of the scroll of a hand-rail with compasses, the first centre being at *a*, the second at *x*; the third centre is said to be at *z*, but it proves to be at *o*; neither *t* nor *w* answer to the remaining centres.

"*To describe the mould for the twist.*—Continue *b* 9 towards M, and F N towards *b* in *Figure* 141; also draw L I parallel to *b* N; at the distance of N K, in any part of N *b*, as at *c*, draw the line *a f* at right angles to *b* N; and on *c* describe the semicircle *a b f*: make *a d* and *f t* each equal to the rise of one stair, and draw the line *d c t*. Make *c* N equal to *c t*; divide *b c* into any number of equal parts and draw the ordinates 15, 1; 16, 2; *k* 3, &c.; divide *c* N into the same number of equal parts as in *b c*, and make the ordinates thereon equal to the ordinates on *b c*, and through their extremes trace the curve N *f*, which is the curve of the outside of the mould. Make *b k* equal to the breadth of the hand-rail; and on *c*, with the radius *c k*, describe the inner semicircle. Make *c h* equal to *r t*. On *k t*, the semi-diameter of the inner semicircle, make ordinates, which transfer on *c h*, as before; and through their extremes trace the curve of the mould, which will complete the whole as required; for as the outlines of the plan of the twisted part of the rail, *b c* and *d e*, are quadrants, therefore the outer and inner curves of the mould will be both a quarter part of two ellipses; because the twisted rail, strictly considered, is no other than the section of a cylinder, as L M I K, whose diameter, *a f*, is equal to twice *a b*, in *Figure* 140, and its transverse diameter equal to *d t*, and conjugate diameter to *a f*.

"The twist of a rail over a circular base at a half pace, as *a b*, figure 142, is the very same thing as the preceding, as being the fourth part of an ellipsis, made by the section of a cylinder, whose diameter is equal to twice *a c*."

This method of forming the section is the same in effect as that already shown by Price. The only difference between Price and Langley is, that Price forms the face-mould of the rail from the intersection of straight lines drawn from two lines of sines placed at right angles to each other, and tracing a curve through the diagonals of the rectangles, beginning at the extremity of one of the perpendiculars, and ending at the extremity of the other. Whereas Langley divides the breadth of the plan and the length of the face-mould of each into the same number of parts, and draws lines at right angles through the points of division, and makes the respective perpendicular of the face-mould equal to those of the plan, and then traces curves through the extremities for the concave and convex sides; and thus completes the face-mould of the twist.

Figures 143, 144.—"*To find the mould of a twisted rail to a circular or elliptical staircase.—Figure* 143. Let A B C D be the plan of a cylindrical staircase, whose base is a circle, and whose stairs wind about the cylinder *a b d*, &c. The plan of the stairs being divided, continue out the diameter *d a*, towards the right hand, as to *f*, of length at pleasure. Make *a f* equal to the girt of the semicircle *a b d*, which divide into the same number of equal parts as there are stairs in the plan of the semicircle *a b d*, as at the points 1, 2, 3, 4, &c. from which erect perpendiculars, as 1 *a*, 2 *a*, 3 *a*, &c. of length at pleasure. Consider the rise of a stair, and make the perpendicular, *f g*, equal to the rise of all the twelve stairs that go round the semicircle *a b d*, and divide the perpendicular *f g* into twelve equal parts, as at the points 1, 2, 3, 4, &c. from which draw lines parallel to *f d*, continued out towards the right hand at pleasure, which will intersect the perpendiculars on the line *f a d*, in the points *ac*, *ac*, *ac*, &c. and which are the breadths and heights of the treads and risers of the twelve stairs at the side of the semi-cylinder *a b d*; for were the whole of *Figure g f a* applied about the semi-cylinder, then the parts *a c*, *a c*, &c. would be in the respective place of each stair. Let *a e* represent the breadth of the hand-rail, and the semicircle *e* 10 *c* its base, over which its inside is to stand. Divide its diameter, *e c*, into any number of equal parts, as at 1, 2, 3, 4, &c. and draw the ordinates 1, 6; 2, 7; 3, 8; 4, 9, &c. which continue upwards, so as to meet the horizontal lines drawn from the perpendicular *g f*, in the points 28, 27, 26, 25, &c. through which trace the ogee curve 28, 14, *a*, which is the sectional line of the cylinder over which it stands. Make the distances, 15, 21; 19, 14; 18, 13; 17, 12; and 16, 11, equal to the ordinates 10, 5; 9, 4; 8, 3; 7, 2; and 6, 1; and through the points 20, 19, 18, 17, 16, to *a* on the line *f d*, trace the curve, 20, 16, *a*, which is the inside curve of the mould, and whose out-curve, 21 *a*, being made concentric thereto, will be the mould required, whose end, 21, 20, when set up in its place, will stand perpendicular over its base *b* 10.

"*Note.* This mould, though made but for one-fourth part of the cylinder, will serve for the whole, by repeating the same, or adding three or more others of the same kind to the ends of each other as often as there are revolutions in the cylinder."

It is not possible to conceive anything so void of truth as the method here shown. Over and above the absence of principle, the description is contradictory to the diagram. We are told to "divide its diameter, *e c* (into any number of equal parts) as at 1 2 3 4, &c. and draw the ordinates 1 6, 2 7, 3 8, 4 9, &c. which continue upwards so as to meet the horizontal lines drawn from the perpendicular *g f*;" but instead of being drawn through the diameter, they pass through the divisions which divide the concave circumference of the plan into equal parts.

Langley has presumed to differ in method from Price in finding the curvature of raking-mouldings; but in this he has been much mistaken, as may be observed in the following:—

"*To find the curvature or mould of the raking ovolo that shall mitre with the level ovolo.*—Let *n p*, *Figure* 145, be a part of the level cornice, and *a n* the points from which the raking-cornice takes its rise, also, let *f a* and *g n* represent a part of the raking-cornice. On *n* erect the perpendicular *n b*, and continue *l a* to *b*; divide *b n* into any number of equal parts at the points 1, 2, 3, &c. and from them draw the ordinates, 1 2, 3 4, 5 6, &c. In any part of the raking ovolo, as at *c*, draw the perpendicular *c m*, and make *c d* equal to *b a*, the projection of the level ovolo. Divide *c m* into the same number of equal parts as are in *b n*, as at the points 1, 3, 5, 7, &c. from which draw ordinates equal to the ordinates in *b n*, and through the points 2, 4, 6, &c. trace the curve required. In the same manner the curvature or mould

may be found when the upper member is a cavetto, cyma-recta, or cyma-reversa, as is exhibited in *Figures* 146, 147, 148."

"*To find the curvature or mould of the returned moulding in an open or broken pediment.*—Let the point *f*, *Figure* 145, be the given point, at which the raking-moulding is to return. Continue *n p* towards *h* at pleasure, and from the point *f* let fall the perpendicular *f h;* draw *f e* parallel to *h p*, and make *f e* equal to *b a*, the projection of the level cornice. Draw *e i* parallel to *f h*, and divide *e g* into the same number of equal parts as are contained in *b n*, as at the points 1, 3, 5, 7, &c. from which draw the ordinates 2 1, 4 3, 6 5, &c. equal to the ordinates in *b n*. Through the points 2, 4, 6, 8, &c. trace the curve required. In the same manner the curvature or mould may be found when the upper member is a cavetto, cyma-recta, or cyma-reversa, as is exhibited in *Figures* 146, 147, 148."

In the treating of a subject in order to make it as perfect as possible, it ought to embrace every article hitherto known that is intimately connected with it; and no author ought to be ashamed to copy an article from another when it comes within his plan; but then he ought to acknowledge his authority, provided that it has not become common property; in this case he may either use it with or without such acknowledgment, as he pleases. There are some authors, however, who, rather than follow the principle of another, will show a different method in order to have the appearance of originality; but as this has every chance of being detected and exposed in future, it must reflect a double disgrace upon their memory. This circumstance is applicable to Langley: it would have redounded to his credit to have copied Price's second method, and to have made honourable mention of his name.

Mr. Abraham Swan has also contributed something to the practical improvement of joinery: his method of describing the scroll is that invented by Vignola; we shall therefore refer the reader to our review upon Price for the detail; but though his face-mould and its application are the same as given by Price, the manner in which he constructs his diagram in order to obtain it is more obvious to the practical joiner, as the corresponding parts of the section may be turned into the same position with regard to the plan, that the section of the solid itself has with regard to its base.

The manner of squaring twist-rails.

Figure 149, "exhibits the pitch-board, to show what part of the step the twisted part of the rail contains; the three dotted lines drawn from the rail to the pitch-board represent the width of the rail, that from the middle shows the ridge, or middle of the rail, which is to be kept level. The dotted lines *a* and *b*, show how much half the width of the rail turns up from its first beginning to 3.

Figure 150, "shows the same pitch-board, with the manner of the rails turning up. If the sides of the twisted part of the rail be shaped by the rail-mould, so that they direct down to its ground-plan; that is, the upper side of the rail being first struck by the mould, then apply the mould to the under side, as much back as the bevel of the pitch-board shows, by being struck on the side of the rail, and then *Figure* 150, being applied to the outside of the rail, from its first twisting part to 3, will show how much wood is to be taken off."

In this part Mr. Swan is so unintelligible, that his reader can only guess at his meaning; by the term *rail-mould* he may either mean the face-mould or the falling-mould; but from the application which he makes of the said *rail-mould*, a practical workman only can discover his meaning to be that of the face-mould.

Figure 151, "exhibits the square of the rail, with the raking-line of the pitch-board drawn through the middle on the upper side; then draw the depth of the side of the rail parallel to this, and the dotted lines from the diagonal of the rail; these lines show what quantity of wood will be wanting on the upper and lower sides of the rail. Set your compasses at *c*, and draw the circular stroke from the raking part of the pitch-board to *b;* take the distance *a b*, and transfer it from *a* to *b*, in *Figure* 152. The several distances thus found, may be set at any number of places, ranging with the straight part of the rail; and it then forms the width of the mould, for the twisting part of the rail.

Figure 152, "shows the sweep of the rail. The rail cannot be fixed less than one-fourth part from the nosing, or front of the step.

"The remaining part of the pitch-board may be divided into any number of parts, as here into four; from these divisions draw lines across the pitch-board to the raking-line, then take the distances from the ground-line of the pitch-board to the plan of the rail, and set them perpendicular from the raking-line of the pitch-board; so shall these divisions, when the rail is in its proper position, lie directly over the divisions on the ground-plan.

"In this Figure, *l*, *m*, and *n*, rise as much above *o*, as the dotted line in *Figure* 151, does above the width of the rail; and they sink as much below *o*, as the other dotted line in *Figure* 151, falls below the width of the rail; the same thicknesses must be glued upon *o*, though the greatest part will come off in squaring. The reason of placing the letters *l*, *m*, *n*, where you see them, is, that they might not obstruct the small divisions of the rail-mould."

This is hardly intelligible to any but Mr. Abraham Swan himself.

Figure 153, "shows how to find the rail, when it takes more than one step. The remaining part of the pitch-board is divided into four parts, as before in *Figure* 152, and it takes in two such parts of the next step. Draw lines from these divisions to the diagonal of the pitch-board, as in *Figure* 152, then take the distance, *a b*, and set it from *c* to *d*, and so proceed with the other divisions.

"Here is also shown another way to find the outside of the rail-mould. Draw all the divisions across the plan of the rail; then take the distance from the ground-line of the pitch-board to 4, transfer it from the diagonal of the pitch-board to 4 on the rail; and so proceed with the other distances. Then, when the rail is put in its proper position, *c* will be perpendicular to *b*, and all the divisions, as 1, 2, 3, 4, &c. in the rail, will be perpendicularly over 1, 2, 3, 4, &c., in the ground-plan."

This method of laying down the face mould is simple, and easily comprehended by every one who understands anything of the nature of a prismatic section.

Figure 154, "shows the plan of a rail of five steps.

"*To find the rail.*—Set five divisions, as from *e* to *h*, which is the height of the five steps; draw the diagonal from *h*, to the plan of the rail; then take the distance *e f*, and transfer it from *g* to *h*, and proceed in the same manner with the other seven distances."

"*To find the width of the rail-mould.*—Draw the lines across the plan of the rail, as at *k*, set that distance from the diagonal to *i;* and so proceed with the rest, as was shown in *Figure* 153.

"Having formed the sides of the rail, perpendicular to its ground-plan, and having squared the lower end of the rail, then take a thin lath, and bend it within the rail, as is represented by *m*, in *Figure* 155."

The general practice of forming the pitching-triangle is by

the number of treads, and the rise in the same number of steps. This is not, however, to be understood of a winding-stair, but of a flight of steps.

"This is the readiest method for squaring a solid rail; but if the rail be bent in the thickness, the nosing of the steps must be drawn upon a cylinder, or some other solid body of a sufficient width to contain the width of the rail, or string-board.

"*r* represents the depth of the rail, touching the nose of each step. You are to take a sufficient number of thicknesses of this width, to make the thickness of your rail; glue them altogether upon your cylinder, or templet, confine them till they are dry, then the rail taken off is ready squared. Proceed in the same manner with the architrave marked *a*."

His method for gluing a rail in thicknesses is the same as Salmon's, but his diagram is better constructed.

Mr. Abraham Swan has also applied the development of a conic frustum to the formation of mouldings upon the spring, round a cylinder, as follows:

Figure 156, "shows the method of bending a cornice round any circular body. When you have found the spring of your cornice, which is shown at the right hand, let the dotted lines be drawn parallel to the spring, and where they intersect the centre, or middle of this body, as in *c*, you will have the radius to strike the curve of your cornice. This principle is as correct as the nature of wood will admit of, and the thinner the wood is, the more exactly will it apply. Besides this, there is another method of forming an annular moulding on a cylinder by thicknesses.

Mr. William Pain has also contributed to the practice of joinery; and though he has not invented any new methods, the plates of his books exhibit the various elevations of stairs, or sections, as they are called, in greater perfection than is to be found in any prior publication: by this means he ascertains the lengths of the rough strings, and the framing of the carriages. He has also shown the stretch-out or development of the rail, and its connection with the string-board, in a more obvious manner to the student, than any of his predecessors. In his *Builder's Pocket Treasury and Practical Builder*, he describes the scroll in the same manner as is to be found in the *British Carpenter*, by Price; his text is, however, very unintelligible. In *Plate* 93, of his *Golden Rule*, third edition, is the following description, engraved on the plate, for finding the face-mould of a hand-rail upon a circular or elliptic plan:—"The method for tracing the raking-moulds for stairs, or any kind of moulding on a cylinder, (see *Figure* 157).—The mould *a* on an ellipsis, and the mould *b* on a circle. Stretch the rise and tread of one quarter, as *a b*, or *c d*, and trace the moulds *a* and *b*, from the plan, as 1, 2, 3, 4, 5, 6, 7, 8, &c. which is plain to inspection." It is not so very plain, nor is there any connection by which its evidence appears. He does not even show how the outer edge of the face-mould is to be obtained: in the diagram it is quite erroneous, its breadth being equal throughout the length of the curve. He tells us to stretch out the rise and tread of one quarter, as *a b*, or *c d*; but on inspecting the diagram, we find that "*a b*, or *c d*," is the hypothenuse of a right-angled triangle, whose base is the tread, and its height the rise of the steps in one quarter: this method is not regulated by principle, but by whim or trial, and is therefore erroneous. In *Plate* 67, of his *Practical House Carpenter*, sixth edition, is a semicircular stair, with winders in the semicircle, and flyers adjoining to the winders, where they begin and end, (see *Figure* 158.) As is usual with Mr. Pain, there is no description of letter-press, and the explanation is contained on the plate, as follows:

"A staircase on a circular plan, drawn half an inch to a foot, with falling moulds and face-mould stretched out, with all the parts figured for practice, the ramps may be traced by the intersection of lines.

"A. Depth of the block for the circular part.

"B. The thickness of ditto."

Figure 159, shows the rail stretched out for the outside falling-moulds, showing the thickness of stuff.

Figure 160, the rail stretched out for the inside falling-mould; and *Figure* 161, the method of getting out the face-mould. In the construction of the face-mould, instead of the rise and tread of the steps, as he writes, on the lines of the figure, we find, by the said diagram, that the diameter and rise of the steps in the semi-circumference are used. Such contradictions entirely confound his readers; and though the latter is nearer to the truth than the rise and treads of the steps, as he writes, the face-mould is far from the pitch, except the wreath were formed for a whole semicircle, as we shall hereafter show; nor can the thickness of stuff be obtained from the stretch-out of the outside falling-mould, as exhibited in *Figure* 159. In the said figure, the reader may also notice the inconsistency of showing the scroll in perspective, while the rail itself is stretched out.

In *Plate* 68, of the said *Practical House Carpenter*, is shown the plan of the rail of a semicircular stair, upon a level landing. *See Figure* 162. He writes thus upon the Plate: "Face-mould for a continued rail on a landing, without winders." In this diagram he uses the diameter and height of one step, which is quite analogous to the method used in the preceding example.

In *Plate* 70, of the said "*Practical House Carpenter*," he shows another stair, upon the same plan as in the first example, (*see Figure* 163;) above is shown an elevation of the rail at *e*, in order to get the thickness of stuff. This diagram certainly shows some idea of the principle, but he has failed in not giving the true delineation with regard to the thickness and depth, and in drawing the two lines which ought to contain the thickness of stuff, to touch the sections at each end, without cutting into them; but to be correct, they should touch the extreme parts. The method of tracing the face-mould is shown in *Figure* 164. It is quite analogous to the two preceding examples. He shows the face-mould in all these examples for the wreath of a whole semi-circumference, which is twice the extent that it ought to be: for though it is not impossible to execute the whole wreath for a semicircle, yet such execution is attended with a prodigious waste of stuff and time; besides the impossibility of matching the grain of the wood. He writes thus upon the plate:

"B. The string-board stretched out for the circular part, (*Figure* 165.)

"*d f*. The hand-rail stretched out.

"*e*. The section of the circular rail, showing the thickness of stuff.

"*c*. The face-mould traced from the plan A, for a solid rail.

"If the rail is bent in thicknesses, *d* and *f*, *Figures* 165, 166, represent the mould drawn a quarter of an inch to a foot."

In *Figure* 167, is his erroneous method of drawing the circular cap with compasses, which has no relation to any principle.

In *Plate* 76, of the said *Practical House Carpenter*, see *Figure* 168, is also shown a stair upon the same plan as in the first example: the method of finding the face-mould is analogous to the first, viz., the diameter of the plan of the rail, and the rise of the steps round the semi-circumference, he forms a mould for the whole semi-circumfer-

ence as before. The elevation of the rail is shown above. See *Figure* 169.

In *Figure* 170, also in the said *Plate* 76, is shown a stair with winders in the quadrantal turnings, and flyers joining the winders. In finding the face-mould, *Figure* 171, the radius of the rail, and the height of the steps in the quadrantal are used, and the face-mould is traced, as in the former examples, and is exactly one-half. Besides the waste of stuff attending this method, it is impossible to match the grain; for if the fibres match the straight rail at one end, they will stand at right angles to those of the straight rail at the other end, in such a stair as the present; and in semicircular turnings the fibres of the wreathed piece would be at right angles to both of the straight parts of the rail. These are not the only disadvantages which accompany this method: as it is evident, that a rail thus got out must be much weaker than one where the fibres run parallel with the chord of the face-mould, neither can it be well secured by bolts at the joints. In Mr. Pain's works, he does not show the application of the face to the plank. However, upon the whole, though he has little or no invention in respect of hand-railing, he has as much originality to claim as any of his predecessors, Price excepted. His orthographical elevations of stairs, though very useful, are very ill projected. In his display of dog-legged staircases, his elevations are tolerably well drawn, see *Figure* 172. He has also been useful in showing the constructions of carriages for geometrical stairs, as they were produced in his time. Though his plates abound in contradictions and false schemes, they show his intention more clearly than some of the preceding authors.

Although the principles of cylindric soffits in an oblique straight wall, where the axis of the cylinder is parallel to the horizon, may be gathered from Price; Pain has exhibited the first example: but the constructions which he gives in his *British Palladio*, and in his *Practical House Carpenter*, are wrong, as we shall show under the article SOFFIT; and yet, in the *British Palladio*, in a similar case, in the covering of polygonal domes, *Plate* 39, *Figures* A, B, C, D, he is right. It is something singular, that the construction which he gives for a circular wall is correct, as shown in his *Golden Rule*, in his *Practical Builder*, in his *British Palladio*, and in his *Practical House Carpenter*.

The method of constructing and gluing up columns is shown in *Plate* 18, of the *Practical House Carpenter*. He shows the methods for gluing on the blocks for carving the leaves in the Ionic and Corinthian capitals, *Plates* 34 and 35, *Practical House Carpenter*.

In *Plate* 63, of the same work, he attempts the construction of raking-mouldings, but fails, as Langley had done before. He also shows, in the same work, how the proportions of the heights of the members of cornices upon a diminished scale are obtained, but neglects to show the projections in the same ratio.

In summing up the whole, we shall omit the several schemes which have failed; and the various authors, with their inventions and improvements, will stand as follow: Price first showed a method for constructing hand-rails, and applied the same to the wreath part of a scroll and to the quadrantal rail on a landing: he also spoke of its application to continued winding stairs, but gave no example. We shall afterwards notice the disadvantages attending his method. This author also gave the first construction of raking-mouldings, in the *Art of Hand-railing*, and Salmon, following Price's principle, gave an example of a continued winding-stair. Langley, in his first example, varied this construction, by applying ordinates dividing the plan and the section into a like number of equal parts, and making the ordinates of the section equal to the corresponding ordinates of the plan; and in this Langley gave the first introduction to ordinates in hand-railing, though ordinates were used by Price in other prismatic constructions.

Swan connected the face-mould with the plan, by placing the pitch-board between them, and so drew ordinates perpendicular to the base of the pitch-board, which he carried up to the hypothenusal line, used as a base to the prismatic section, and then drawing ordinates to such base, made the corresponding ordinates of the section equal to those of the plan, and thus completed the face-mould. This was certainly an improvement upon Langley's first method, as by this means it became more evident to the reader. The methods, however, shown by Langley and Swan, were in effect the same as Price's; that is, they would give the same moulds, under the same data or circumstances, and consequently would partake of the same advantages or disadvantages, as we shall exemplify at the end of this article.

The application of the surface of the frustum of a cone was first applied by Swan, to mouldings bent to the spring round a cylindric body. Pain followed the scheme of ordinates laid down by Swan, and constructed his falling-moulds in a more eligible manner than any of the preceding authors; but he is very inconsistent in a disagreement between his text and his diagrams, as well as in showing his moulds for the formation of rails, answering to a complete semicircular plan.

There are several particulars with respect to hand-railing to be observed on the whole; in all the wreaths hitherto constructed, the joints are always made at the spring, viz., at the dividing surface, between the straight and circular parts, and the fibres of the wood will always run perpendicular to those of the straight rail, at one end at least; by this means the fibres, or grain, as they are called, are ill-matched, and the wreath becomes extremely weak at the joint. In none of these methods shown by Langley and Swan, which in effect are Price's, will the section coincide in any more than any one point on the top of the lower extremity of the wreath, and this circumstance, therefore, occasions a vast waste of stuff, as we shall presently prove. Pain also showed the method of constructing columns; forming and gluing up capitals, in order to be carved; with the formation of a cylindro-cylindric soffit, when the axis of the cylindric opening was in a plane perpendicular to the axis of the cylindric wall. The construction of a pediment in a circular wall was also tried by this author, and so far as he proceeded he was correct, but was deficient in not giving the whole of the requisite moulds and instructions, which rendered what he had done of no value.

We have now noticed all the methods that may be considered either as inventions or improvements in the art of joinery, and we trust that the account is impartial, and what every one inclined to do justice will find to be the case; and if anything has been mistaken, it is occasioned by the disagreement between their text and diagrams, and not from any intention to lessen their merit, or the value of their works.

Mr. Nicholson has invented the method for the development of a conic soffit in a circular wall, or of a conic surface terminated by a plane, or by a cylindric surface. And though the cuneoidal surface is not capable of development, he has shown how it may be unfolded, so as to terminate upon a plane or cylindric surface, by a method which comes very near to the truth.

He has discovered an entire new principle of squaring the wreath of a hand-rail, by which the face-mould may touch the tops of two vertical sections at each end, either in one of

its angular points or in its whole breadth, supposing both the wreath and the mould to be set up in the true pitch.

He has invented a method of tracing the mitre-cap for the hand-rail, as used in dog-legged staircases, from a given section of the rail.

He has invented a method of gradating the steps, so as to form a regular surface upon the soffit at the junction of the flyers and winders; this not only gives an easy turn to the skirting, but permits the rail to be kept at a uniform distance from the nosings of the steps.

He was the first that showed a development of the plank, in order to apply the face-mould, and to range the two sides in the cylindric or prismatic surfaces according to the plan of the rail.

In the article HAND-RAILING, he has shown a more regular method of lescribing the spiral lines of the scroll, by finding the centres in a fret or right-angled guilloche; so that the difference of any two adjoining sides of the fret will be always the same. In order to describe the scroll with compasses, he also invented the method of regulating the difference of radii of a scroll by a line of sines; as had formerly been done by a line of tangents, in order to trace the scroll by hand.

He was the inventor, and the first that showed the method of getting the scroll out of the solid, without gluing any part.

The method of apping an iron rail was never practised with certainty until his invention appeared in the *Carpenter's Guide*.

He was the inventor of the method of springing the plank, by making its plane of inclination to rest upon three vertical sections of the wreath, viz., one at each end and one in the middle, being obtained by three heights taken from the falling-mould. By this means the thickness of the rail is ascertained with certainty, and will never exceed $2\frac{1}{2}$ inches where the rail is intended to be 2 inches deep, and $2\frac{1}{4}$ inches broad; whereas, by former methods, the plank would require to be 6 or 8, or even 10 inches thick.

No author before him ever regulated the pitch of the plank by the falling-mould, but by the height of the steps only; by this he obtained an immense saving of stuff.

He also invented the method of cutting the veneers in thickness, so that the rail may come off squared from the cylinder.

He was the first author that showed the method of scribing down the skirting upon stairs, however irregular the steps might be in respect of each other.

He also invented a method for squaring the bars for the head of a sash in a circular wall; no method had been ever shown before by which such work might be executed.

He invented, and was the first to show, a method for the formation of a circular architrave in a circular wall.

Besides Price's method of raking mouldings, he added that for the angle-bars of a polygonal window, such as are used in shop fronts.

He improved the method of proportioning mouldings, by showing how the projections were to be found in the same ratio with the heights, which had been neglected by other writers.

He was the first that treated upon hinging, and the hanging of doors and shutters, and the various kinds of folding joints.

In *Figure* 176, No. 1, A B C D E F G H I is half the ground-plan of a continued rail, viz., where the risers are equal to each other, as are likewise the heads.

Figure 177 shows the falling-mould, and the development below it, to the quadrant E F G H I; and because the risers and treads are all equal, the edges of the falling-mould will be straight lines parallel to each other: *e f g h i*, No. 2, is an orthographic projection of the quarter of the rail, corresponding to E F G H I, No. 1; in No. 2, draw L V parallel to A I, No. 1; make the angle V L M, No. 2, equal to the angle which the edge of the falling-mould makes with the base of the development in *Figure* 177; through *i* draw K N parallel to L M; through N draw N M perpendicular to L M; through L draw L K parallel to M N; then M N or L K will be the thickness of stuff necessary, according to the method given by Price and Swan.

a b c d e f g h i, No. 3, is a projection of the rail to the whole semi-circumference. We shall now show the thickness of stuff according to Pain. It will be recollected that he finds the pitch of the rail by the diameter or semi-diameter, and the rise of the steps in the semi-circumference or quarter accordingly: suppose, then, there are eight steps in the semi-circle, now *w y* is the diameter, and *y x* the rise of eight steps; therefore join *w x* and you have the line of section of the cutting-plane: through *a* draw R S parallel to *w x*, and through *i* draw Q T, also parallel to *w x:* draw T S and Q R perpendicular to *w x;* then the breadth Q R or T S, and the length Q T or R S of the rectangle Q R S T, will be respectively the thickness and length of the stuff.

The projection of the upper half of No. 3 is equal and similar, and similarly situated to No. 2; the lower half of No. 3 is equal and similar to the upper part when reversed, the lower part at *a b c d* showing the soffit, and the upper, *f g h i*, the back or top of the rail.

Figure 178 shows the projection for a quarter of the rail, upon a plane parallel to one of the radii: this shows an equal thickness to that shown at No. 3, *Figure* 176, the pitch being obtained from the radius, and the height of the steps in a quarter of the circumference.

Figure 179 shows the method of finding the face-mould, according to the first invention of Nicholson, shown in the *Carpenter's New Guide*, where the cutting plane of the cylinder is perpendicular to the plane of the chord of the rail, and passes through the upper corners of the sections at each end. *Figure* 180 shows the projection upon a plane parallel to the chord of the plan, agreeable to the face-mould, *Figure* 179. All these projections are made agreeable to one pitch-board, *Figure* 177.

We shall now show the quantity of stuff according to each method. *Figure* 181 is a development of the plank, showing the application of the face-mould according to Price, together with the thickness, the length, and breadth of the plank. The particular measures are to be taken from the subjoined scale.

	Ft.	In.	
The length measures	1	5	which reduced to inches, gives 17.
The breadth	0	$8\frac{1}{2}$	
The thickness	0	6	

By these measures we obtain 867 solid inches in the quantity of stuff required by Price's method.

Figure 182 is a development of the plank according to the pitch and face-mould required by Pain's method, for a whole semi-circumference.

	Ft.	In.	
The length measures	2	10	which reduced to inches, gives 34.
The breadth	0	$8\frac{1}{2}$	as in Price's.
The thickness	0	$4\frac{1}{2}$	

By these measures we obtain $1{,}300\frac{1}{2}$ solid inches in the quantity of stuff for a whole semi-circumference, as required by Pain's method.

Figure 183 is a development of the plank for a quarter of the circumference, as required by Pain's method.

	Ft.	In.	
The length measures	1	8	which reduced to inches, gives 20.
The breadth	0	8½	as before.
The thickness	0	4½	

By these measures we obtain 765 solid inches required by Pain for one quarter of the circumference.

Figure 184 is a development of the plank, showing the quantity of stuff according to the method used by Nicholson.

	Ft.	In.	
The length measures	1	8½	which reduced to inches, gives 20½.
The breadth	0	4	
The thickness	0	3	

By these measures we obtain 246 solid inches for the quantity of stuff, by the method invented by Nicholson.

From these calculations, it appears that if the quantity of stuff which Nicholson's method requires, be called *unity*, or *one*, Pain's method will require three times as much, and that invented, or first presented by Price, three and a half times as much. In these we have only compared the numbers answering to the solidity of one quarter of the circumference, as the formation of a rail for the whole semi-circumference would be ridiculous, not only on account of the quantity of stuff, but the impossibility of being able to match the fibres at the joint, as has been before observed.

It may, however, be observed, in Pain's method, that though the quantity of stuff required for one quarter of the circumference be much greater than the necessary quantity, yet the thickness and breadth for a whole semi-circumference does not appear extra for such a large portion of the rail.

It may also be observed, that none of the preceding authors ever followed a falling-mould, nor has only one of them brought the solid of the wreath into the straight of the rail. If these had been done, the thickness of stuff required would have been much greater than that required for the quadrantal part of the circumference only.

It is remarkable that they should have made the sections of the prism for the face-mould upon a plane perpendicular to one of the radii, and consequently parallel to the other radius of the quadrantal plan, as the rail requires much thicker stuff in this position than any other they could have chosen

Figure 185 shows the several inclinations according to the plane of section: A B C is the inclination according to Price and his followers; A B E is that according to Pain; and A B D that practised by Nicholson; which indeed is the only inclination founded upon principle, and is nearly an arithmetical mean between the other two; that used by Pain being too high, and that by Price too low.

It has already been observed that the method of preparing the scroll, by gluing blocks side by side, was very incorrect, being founded only in whim: and though gluing up scrolls in parallel blocks is not an approved method, nor ought to be so, yet it may not be amiss to show the true principle. Let *Figure* 185 be the plan of the scroll, the shank being formed by the parallel blocks K B, E C, F D, glued to the block or central part, which forms the eye. *Figure* 186, the falling-mould, the heights k l, a m, b n, c o, d p, i q, are those upon the points A, B, C, D, on the plan, and the height h r that upon F or H. *Figure* 187 is an elevation or projection of the blocks, showing the method of gluing them together; the heights *k l*, *a m*, *b n*, *c o*, *d p*, are respectively equal to the corresponding heights in *Figure* 186. This *Figure*, viz., 187, shows how the blocks are to be formed before they are put together.

In addition to the copious treatise given on this article, the following general description will be found very useful.

Plate XVI.—*Figures* 1, 2, 3, 4. *The method of hinging folding-doors.*—Suppose the bead to be drawn on both sides of the door; so that a plane parallel to, and equidistant from, either jamb, may bisect each of the beads, and the joint to be formed alike on both sides of this plane: Let C be the centre of the hinge, and B the arris on the plane side of the quirk next to the bead; join C B; draw B D at right angles, cutting the concentric circle, G E, which bisects the thickness of the door in G; also let F be the arris on the plane side of the quirk of the opposite bead on the alternate side: draw F E parallel to B D; then B G E F will be the joint required.

Figure 5.—*To make a door swing either way, supposing the jamb formed alike on both sides.* Let A and B be the points where the faces of the door intersect the jambs; join A B, and bisect it in C; draw C D perpendicular to A B, and make C D equal to A C or C B; on D, as a centre, with the radius D A or D B, describe the arc A B; and A B will be the joint required.

Figure 6.—*To make the joints correspond to a rebate on the opposite jamb or lintel.*—Let A and C be the points where the faces of the door intersect the jamb; produce D C, the face of the door, to B, and draw A B perpendicular to B D; make B D equal to A B; join A D and A C; bisect A C in E; draw E F perpendicular to A C, cutting A D at F; from F, as a centre, with the distance F A, or F C, describe the arc A C, which will be the joint required.

Figure 7.—*The method of concealing the revolving joint of doors or shutters.*—Make the angle F A E half a right angle; place the centre of the hinge at B, in the line A E, and let the hinge be so constructed that the two sides of the cavity, or hollow, may form a right angle.

JOINT, the surface of separation of two bodies brought into contact, and held firmly together either by a glutinous liquid, or by opposite pressures, or by the weight of one body lying upon the other. A joint is, however, not the mere contact of surfaces, but the nearer they approach the more perfect is the joint. Perhaps two pieces of wood adhering together by means of glue, or other such tenacious liquid, between two plane surfaces, is the most perfect. In masonry, the distances of the planes intended to form a joint are very considerable, owing to the coarseness of the particles which enter the composition of the cement.

JOINTER, in joinery, the largest plane used by the joiner to straighten the face or edge of the stuff which he is preparing.

Jointer, in bricklaying, a crooked piece of iron, forming two curves of contrary flexure by its edges on each side, used for drawing the coursing and vertical joints by the edge of the jointing-rule.

JOINTING RULE, a straight edge used by bricklayers for regulating the direction or course of the jointer, in the horizontal and vertical joints of the brickwork.

JOISTS, one or more horizontal rows of parallel equidistant timbers in a floor, on which the flooring is laid. There are three kinds of joists, viz., binding-joists, bridging-joists, and ceiling-joists.

JONES, INIGO, a celebrated architect, born in London about 1572. He was bred a joiner, but his skill in drawing recommended him to the notice of the earl of Pembroke; who sent him to Italy, where he acquired a complete knowledge of architecture. James I. made him surveyor-general of his works, which office he discharged with great fidelity. He continued in the same post under Charles I., and had the

superintendence of the building of S . Paul's, Covent-garden; with the management of the masques and interludes for the entertainment of the court. This brought him into a squabble with Ben Jonson, his coadjutor, who ridiculed him in his comedy of *Bartholomew-fair*, under the name of *Lantern Leatherhead*. He suffered considerably during the time of Cromwell, so that grief, misfortunes, and age, brought him to his grave in July, 1651. In 1655, appeared his *Discourse on Stonehenge*, in which he attempts to prove it to have been a Roman temple. As an architect, Inigo generally, but not always, shines to great advantage. He designed the palace of Whitehall and the Banqueting-house, the church and piazza of Covent-garden, Coleshill in Berkshire, Cobham-hall in Kent, and various other buildings, public and private. The principal of his designs were published in folio, in 1727, and some in 1744.

JUFFERS, stuff about four or five inches square, of any length. This term is not now in use, though frequently found in old books.

JUMP, in masonry, one among the very numerous appellations given to the dislocations of the strata, by practical miners of different districts.

JUMPER, a long iron tool, with a steel chisel-like point, used in quarries and mines for drilling or boring shot-holes in rocks which require to be blasted with gunpowder. *Drill*, *neger*, and *gad*, are other terms by which this tool is called.

K.

KEN

KAABA. *See* CAABA.

KALEIDOSCOPE, an optical instrument, the invention of Sir David Brewster. It creates and exhibits, by reflections, a variety of beautiful colours and symmetrical forms; so that such as may be deemed appropriate, may be made use of for patterns, as in carpets, and for other purposes of ornamental design.

KAOLIN, a species of clay, one of the two ingredients in Chinese porcelain.

KEEP TOWER, the middle, or principal tower in a castle. *See* CASTLE.

KEEPING, to be in keeping with, or harmonize with,—a technical term used in painting, and signifying the peculiar management of those parts of the art, colouring and chiaro-scuro, which produces the proper degree of relievo in objects admitted into a composition; according to their relative positions in the imagined scene, and the degree of importance the artist attaches to them.

KENILWORTH CASTLE, is famed in the annals of Warwickshire for its antiquity. "This ancient castle," says Dugdale, "was the glory of all these parts, and for many respects may be ranked, in a third place at the least, with the most stately castles of England." This fortress was built by Geoffry de Clinton, in the time of Henry I. He was chamberlain and treasurer to that monarch. By subsequent kings and occupiers it was greatly enlarged and strengthened at different times: and in the various civil and domestic wars of England, it was frequently the object of contention with different monarchs and nobles. Edward II. was confined for a time in Kenilworth Castle, shortly before his murder in Berkley Castle, (A.D. 1327). In the following reign, John of Gaunt became owner of the castle, which he much augmented by new and magnificent buildings. Henry IV., son of John of Gaunt, united the castle, which he inherited, to the domains of the crown, of which it formed part till the time of Elizabeth, who granted it to Robert Dudley, Earl of Leicester. The magnificent entertainment given here by Leicester to Elizabeth, has been made familiar to the general reader by Sir Walter Scott's historical romance of "Kenilworth." After the civil war of Charles I., the castle was dismantled, but extensive and picturesque ruins remain. What remains of the buildings shows that the whole was an immense and spacious pile; consisting of an outer wall with bastion towers, a tilt-yard, with towers at each end; and several buildings within the ballium, or base-court. The area within the walls consists of seven acres. There were four gatehouses, and the walls were from ten to fifteen feet in thickness. At a short distance from the castle was a priory for Black Canons; of which buildings, parts of the gateway and chapel remain. Near these is the parish church, the western door-way of which is a curious specimen of ancient architecture.

KEY

KERF, the way made by a saw through a piece of timber, by displacing the wood with the teeth of the saw.

KEY, in a general sense, a fastener; that which fastens, as a piece of wood in the frame of a building, &c.

KEY or COTTAR, in engineering, a wedge-shaped or tapering piece of iron or wood; which is driven firmly into a mortise prepared to receive the same, to tighten and secure the several parts of any framing or contrivance together, as a rail to a chair, &c., forming a fastening. When a key is passed through a timber-beam, or two or more thicknesses of metal or other material, placed side by side, it is customary to clasp them together by *gibbs*, previous to inserting the key.

KEY, now more commonly spelt QUAY, a long wharf by the side of a harbour, river, or canal, furnished with posts, and rings, whereby ships and boats may be secured; also with cranes, capstans, and other convenient mechanism for loading and unloading.

KEY, an instrument for locking and unlocking doors. *See* LOCK.

KEY, of a floor, the last board that is laid.

KEYED DADO, that which is secured from warping by bars grooved into the back; see the following article.

KEY-HOLE, a hole or aperture in a door or lock, for receiving a key.

KEY-PILE, the centre pile plank of one of the divisions of sheeting-piles contained between two gauge piles of a coffer-dam or similar work. It is made of a wedge-form, narrowest at the bottom, and, when driven, keys or wedges the whole together.

KEYS, in naked flooring, pieces of timber framed in between every two joists, by mortise and tenon; and when driven fast between each pair, with their ends butting against the grain of the joists, are called *strutting pieces*.

KEYS, in joinery, pieces of timber let into the back of a board, transverse to the fibres, and made of one or several breadths of timber, either by a dovetailing, or by first making a groove equal to the width of the keys, and then cutting narrow grooves in the sides of the first-made groove close to the bottom, preserving a sufficient substance at the top of each

Keys are used for the purpose of preventing boards from warping.

Dado, when made of broad boards, glued together, should always be keyed. *See* DADO.

KEY-STONE, of an arch or vault, the last stone placed on the top thereof; which, being wider and fuller at the top than at the bottom, wedges, as it were, and binds in all the rest.

M. Belidor makes the thickness of the arch-stones of a bridge, one twenty-fourth part of the width of the arch; but Mr. Gautier, another experienced engineer, makes their length, in an arch 24 feet wide, 2 feet; in arches, 45, 60, 75, 90 wide, 3, 4, 5, 6 feet respectively; and it is observed by Mr. Muller, that the thickness allowed by Belidor is not sufficient to prevent the weight of the arches from crushing the key-stones to pieces by their pressure against one another.

The name *key-stones*, or *arch-stones*, is sometimes also given to all the stones which form the sweep of an arch, or vault, answering to what the French more distinctly call *voussoirs*.

KILDERKIN, a liquid measure, which contains two firkins, or eighteen gallons. Two kilderkins make a barrel, and four a hogshead.

KILN, a kind of oven, or stove, for admitting heat, in order to dry substances of various kinds, as corn, malt, hops, &c. It also signifies a fabric or building constructed for the purpose of burning limestone, chalk, and other calcareous stones, into lime. Kilns are of different kinds, and formed in different ways, according to the purposes for which they are designed.

KILN, *Brick*. *See* BRICK.

KILN, *Hop*, a stove or kiln for the purpose of drying or stoving hops.

KILN, *Lime*, a sort of kiln constructed for the purpose of burning lime. The operation called burning lime, consists in exposing marble, limestone, chalk, oyster-shells, or any other carbonate of lime, for some time to a white heat, by which means the carbonic acid and water contained in these substances are expelled; and the earth, which has the peculiar characters assigned to lime, is left behind in a mass which has little coherence, and is therefore easily reduced to powder. It is usually called quick-lime after calcination. Newly prepared, it absorbs water with great avidity; it will absorb one-fourth of its weight of that fluid, and still remain perfectly dry. If a sufficient quantity of water be poured upon it, the lime falls into powder; some of the water is converted into vapour by the disengaged caloric of that part which unites with the lime; this is called the slacking of lime; if the quantity slacked be considerable, and performed in a dark place, light will be observed as well as heat. Kilns are built of different forms or shapes, according to the manner in which they are to be wrought, and the kinds of fuel to be employed. It may be remarked, that, in places where materials are dear, from their being fetched from a distance, and where the fuel is coals, and also expensive, the form of a kiln is mostly that of an inverted cone, a form which has its inconveniences; but in districts where the art of burning lime is practised with superior attention and correctness, the form has of late years been gradually changing from conical to elliptical. Some writers are of opinion, that the best form of a lime-furnace, in the established practice of the present day, is that of an egg placed upon its narrower end, having part of its broader end struck off, and its sides somewhat compressed, especially towards the lower extremity; the ground-plot or bottom of the kiln being nearly an oval, with an eye, or draft-hole, toward each end of it. It is supposed that two advantages are gained by this form, over that of the cone. By the upper part of the kiln being contracted, the heat does not fly off so freely as it does out of a spreading cone. On the contrary, it thereby receives a degree of reverberation, which adds to its intensity. But the other, and still more valuable effect, is this: when the cooled lime is drawn out at the bottom of the furnace, the ignited mass, in the upper parts of it, settles down, freely and evenly, into the central parts of the kiln; whereas, in a conical surface, the regular contraction of its width, in the upper as well as the lower parts of it, prevents the burning materials from settling uniformly and levelling downward. They *hang* upon the sides of the kiln, and either form a dome at the bottom of the burning mass, with a void space beneath it, thereby endangering the structure, if not the workmen, employed; or, breaking down in the centre, form a funnel, down which the underburnt stones find their way to the draft-holes. And the contraction of the lower part of the kiln has not the same effect; for, after the fuel is exhausted, the adhesion ceases, the mass loosens, and, as the lime cools, the less room it requires. It therefore runs down freely to the draft-holes, notwithstanding the quick contraction of the bottom of the kiln or surface.

Lastly, with respect to the lime-furnace, the fire requires to be furnished with a regular supply of air. When a kiln is first lighted, the draft-holes afford the required supply. But after the fire becomes stationary in the middle, or towards the upper part of the kiln, (especially of a tall kiln,) while the space below is occupied by burnt lime, the supply from ordinary draft-holes becomes insufficient. If the walls of the kiln have been carried up dry or without mortar, the air finds its way through them to the fire. In large deep kilns that are built with air-tight walls, it is common to form air-holes in their sides, especially in front, over the draft-holes. But these convey the air, in partial currents, to one side of the kiln only, whereas that which is admitted at the draft-holes passes regularly upward to the centre, as well as to every side of the burning mass; and, moreover, tends to cool the burnt lime in its passage downward, thereby contributing to the ease and health of the workmen. Hence, it is to be observed, the size of the draft-holes ought to be proportionate to that of the kiln and the size of the stones taken jointly, (air passing more freely among large than among small stones,) and the required supply of air should be wholly admitted at the draft-holes. By a sliding or a shifting valve, the supply may be regulated, and the degree of heat be increased or diminished, according to circumstances.

The most ancient kind of lime-kiln is probably that which is made by excavating the earth in the form of a cone, of such a size as may be necessary; and afterwards building up the sides, or not, according to the circumstances of the case; the materials being then laid in, in alternate layers of fuel and stone, properly broken, until the whole is filled up. The top is then covered with sods, in order that the heat may be prevented from escaping; and the fire lighted at the bottom, and the whole of the contents burnt, in a greater or less space of time, in proportion to the nature of the stone, and the quantity that is contained in the kiln. From the circumstance, of the top parts of these kilns, in some districts, being covered over and the sides sometimes built up with sods, they are termed *sod-kilns*, in order to distinguish them from the other sorts. When the whole of the contents of such kilns are grown cold, they are drawn or taken out from the bottom; and the kiln again filled, if necessary. These kilns are obviously intended for burning only one kiln-full at a time. But as the burning of lime in this way is tedious and uneconomical, other methods and forms of kilns have

been had recourse to. Where lime is much wanted, either for building or other purposes, they use perpetual kilns, or what are more generally known by the name of *draw-kilns*. These, as all lime-kilns ought to be, are situated by the side of a rising bank, or sheltered by an artificial mound of earth. They are generally built either of stone or brick; but the latter, as being better adapted to stand excessive degrees of heat, is considered as preferable. The outside form of such kilns is sometimes cylindrical, but more generally square. The inside should be formed in the shape of a hogshead, or an egg, opened a little at both ends, and set on the smallest; being small in circumference at the bottom, gradually wider towards the middle, and then contracting again towards the top. In kilns constructed in this way, it is observed, fewer coals are necessary, in consequence of the great degree of reverberation which is created, above that which takes place in kilns formed in the shape of a sugar-loaf reversed. Near the bottom, in large kilns, two or more apertures are made: these are small at the inside of the kiln, but are sloped wider, both at the sides and the top, as they extend towards the outside of the building. The uses of these apertures are for admitting the air necessary for supplying the fire, and also for permitting the labourers to approach with a drag and shovel, to draw out the calcined lime. From the bottom of the kiln within, in some cases, a small building, called *a horse*, is raised in the form of a wedge, and so constructed as to accelerate the operation of drawing out the burned limestone, by forcing it to fall into the apertures which have been mentioned above. In other kilns of this kind, in place of this building, there is an iron grate near the bottom, which comes close to the inside wall, except at the apertures, where the lime is drawn out. When the kiln is to be filled, a parcel of furze or faggots is laid at the bottom; over this a layer of coals; then a layer of limestone, which is previously broken into pieces, about the size of a man's fist; and so on alternately; ending with a layer of coals, which is sometimes, though seldom, covered with sods or turf, in order to keep the heat as intense as possible. The fire is then lighted in the apertures; and when the limestone towards the bottom is completely calcined, the fuel being considerably exhausted, the limestone at the top subsides. The labourers then put in an addition of limestone and coal at top, and draw out at bottom as much as they find thoroughly burned; and thus go on, till any quantity required be calcined. When limestone is burned with coals, from two-and-a-half to three-and-a-half bushels, on a medium, three bushels of calcined limestone are produced for every bushel of coals used in the process.

A lime-kiln of this sort is described in Count Rumford's *Essays*, in the possession of the Dublin Society, as well as the principal objects that ought to be had in view in constructing the kiln pointed out: the first of which is, to cause the fuel to burn in such a manner as to consume the smoke, which has here been done by obliging the smoke to descend and pass through the fire, in order that as much heat as possible might be generated. Secondly, to cause the flame and hot vapour which rise from the fire to come in contact with the lime-stone by a very large surface, in order to economize the heat, and prevent its going off into the atmosphere; which was done by making the body of the kiln in the form of a hollow truncated cone, and very high in proportion to its diameter; and by filling it quite up to the top with lime-stone, the fire being made to enter near the bottom of the cone.

"Thirdly, to make the process of burning lime perpetual, in order to prevent the waste of heat which unavoidably attends the cooling of the kiln, in emptying and filling it, when, to perform that operation, it is necessary to put out the fire.

"And fourthly, to contrive matters so that the lime in which the process of burning is just finished, and which, of course, is still intensely hot, may, in cooling, be made to give off its heat in such a manner as to assist in heating the fresh quantity of cold limestone with which the kiln is replenished, as often as a portion of lime is taken out of it.

"To effectuate these purposes, the fuel is not mixed with the limestone, but is burned in a close fire-place, which opens into one side of the kiln, some distance above the bottom of it. For large lime-kilns on these principles, there may be several fire-places all opening into the same cone, and situated on different sides of it: which fire-places may be constructed and regulated like the fire-places of the furnaces used for burning porcelain.

"At the bottom of the kiln there is a door, which is occasionally opened to take out the lime.

"When, in consequence of a portion of lime being drawn out of the kiln, its contents settle down or subside, the empty space in the upper part of the kiln, which is occasioned by this subtraction of the burned lime, is immediately filled up with fresh limestone.

"As soon as a portion of the lime is taken away, the door by which it is removed must be immediately shut, and the joinings well closed with moist clay, to prevent a draught of cold air through the kiln. A small opening, however, must be left, for reasons which are explained below.

"As the fire enters the kiln at some distance from the bottom of it, and as the flame rises as soon as it comes into this cavity, the lower part of the kiln (that below the level of the bottom of the fire-place) is occupied by lime already burned; and as this lime is intensely hot, when, on a portion of lime from below being removed, it descends into this part of the kiln; and as the air in the kiln, to which it communicates its heat, must arise upwards in consequence of its being heated, and pass off through the top of the kiln, this lime, in cooling, is by this contrivance made to assist in heating the fresh portion of cold limestone with which the kiln is charged. To facilitate this communication of heat from the red-hot lime just burned, to the limestone above in the upper part of the kiln, a gentle draft of air through the kiln, from the bottom to the top of it, must be established, by leaving an opening in the door below, by which the cold air from without may be suffered to enter the kiln. This opening (which should be furnished with some kind of a register) must be very small, otherwise it will occasion too strong a draft of cold air into the kiln, and do more harm than good; and it will probably be found best to close it entirely, after the lime in the lower part of the kiln has parted with a certain proportion of its heat."

It is a common practice in some places to burn limestone with furze. The kilns which are made use of in these cases are commonly known by the denomination of *flame-kilns*, and are built of brick; the walls from 4 to 5 feet thick, when they are not supported by a bank or mound of earth. The inside is nearly square, being 12 feet by 13, and 11 or 15 feet high. In the front wall there are three arches, each about 1 foot 10 inches wide, by 3 feet 9 inches in height. When the kiln is to be filled, three arches are formed of the largest pieces of limestone, the whole breadth of the kiln, and opposite to the arches in the front wall. When these arches are formed, the limestone is thrown promiscuously into the kiln to the height of 7 or 8 feet, over which are frequently laid fifteen or twenty thousand bricks, which are burned at the same time with the limestone. When the filling of the kiln is completed, the

three arches in the front wall are filled up with bricks almost to the top, room being left in each sufficient only for putting in the furze, which is done in small quantities, the object being to keep up a constant and regular flame. In the space of thirty-six or forty hours, the whole limestone, about 120 or 130 quarters, together with 15,000 or 20,000 bricks, are thoroughly calcined. Kilns constructed in this way may be seen near Wellingborough, in Northamptonshire, and other places in the northern parts of the kingdom. In many of the northern counties of Scotland, which are situated at a great distance from coal, it is also a common practice to burn limestone with peat; and, considering the rude ill-constructed kilns which are used for the purpose, it is astonishing with what success the operations are performed. In some of these districts, it is stated that limestone is sufficiently calcined with peats, laid *stratum super stratum*, in kilns formed of turf; but owing to the quantity of ashes which fall from the peat, the quality of the lime is considerably injured; and, from the open and exposed situation of many of these kilns, the waste of fuel is immense. But the most common method of burning limestone with peat, is in kilns constructed somewhat similar to those in the districts where furze is used as the only fuel. In kilns of this description there are, in general, only two arches, or fire-places, and the peats are thrown into the bottom of these arches, the fronts of which are seldom closed up, by which means the wind has often great influence in retarding the operation, and frequently prevents the complete calcination of the limestone. An improvement might, it is supposed, be made on these kilns at a very trifling expense: if an iron grate were laid across the bottom of the arch, with a place below for the ashes to fall down, and the front of the arch closed up by a door made of cast-metal, one-third of the fuel might be saved, and the operation performed in a shorter time, and with a much greater certainty, than by the method now practised in such kilns.

In a communication to the Board of Agriculture, Mr. Rawson described a method of constructing a lime-kiln, by which a considerable saving of fuel was effected.

This kiln was made 20 feet in height; at the bottom was placed a metal plate, one foot in height, intended to give air to the fire; the sloped sides were 6 feet in height, the breadth at the top of the slope 8 feet; the sides carried up perpendicular 14 feet; so that every part of the inside, from 14 feet to the mouth, was exactly of the same dimensions. On the mouth of the kiln was placed a cap, built of long stones, and rather sharply contracted, about 7 or 8 feet high. In the building of this cap, on one side of the slope, the mason being over the centre of the kiln, anything dropping down would fall perpendicularly to the eye beneath. Here was placed an iron door 18 inches square, and then the remainder of the building of the cap was carried up until the whole of the top was contracted to 14 inches. The kiln was fed through the iron door, and, when filled, the door was close shut. The outside wall was 3 feet at the bottom battering up to 2 feet at top, and built at such a distance from the inside wall of the kiln, that 2 feet of yellow clay might be well packed in between the walls; without this precaution kilns are almost certain to split. At 8 feet high from the eye of the kiln, two flues were carried through the front wall, through the packed clay to the opposite side of the kiln, to give power to the fire. It is asserted, that, with this kiln, one-third more lime has been produced from a given quantity of fuel, and also that stones of bad quality might be put into the kiln without the necessity of being broken so small as usual. As many situations will not admit of building a kiln 20 feet high, while other situations may allow of its being built 30, or even 40 feet, (for it cannot be made too high,) the diameter of the kiln should be proportioned to the height to which it is carried up.

In the same communication, Mr. Rawson also described another and rather curious application of this sort of contrivance. He states that, "for several years, he has made use of a small kiln in an outside kitchen, the height 9 feet, the diameter $3\frac{1}{2}$ feet. In the side of the kiln next the fire, he had 3 square boilers placed, one of them large, containing half a barrel, with a cock, which supplied the family with constant boiling water; for the two others, he had tin vessels made to fit the inside with close covers, in which meat and vegetables with water were placed, and put into the two smaller boilers, which never had any water, but had close covers. The tin boilers were heated sooner than on the strongest fire, and when the meat, &c., were sufficiently dressed, the whole was taken out of the metal boilers. At one side he had an oven placed for roasting and boiling meat; the bottom was metal of 26 inches diameter, and $1\frac{1}{2}$ inch thick, a flue from the fire went underneath. Even with the bottom of the oven, a grating 9 inches square was placed, which opened a communication between the oven and the hot fire of the kiln. The height of the oven was 14 inches, shut close by a metal door of 18 inches square, and the top, level with the mouth of the kiln, was covered by another metal plate of half an inch thick, on which was placed a second oven; the heat which escaped through the half-inch plate, though not near the fire, was sufficient to do all small puddings, pies, breakfast-cakes, &c. &c. The meat in the large oven was placed on an iron frame, which turned on a pivot, and stood on a dripping-pan, and was turned by the cook every half hour. And over the kiln he had a tiled stage for drying corn, and a chimney at one side, with a caul on the top, which carried off all steam and sulphur: a large granary was attached to the building." It is added, that the lime, if sold, would more than pay for fuel and attendance; and he has frequently had dinner dressed for fifty men, without interfering with his family business in any great degree.

An admirable combination of a lime-kiln, with a coke-oven, was the subject of a patent granted to Mr. Charles Heathorn some years ago, since which time it has been in successful operation at Maidstone and other places. The object of this invention, as expressed in the specification of the patent, is the preparation of quick-lime and coke in the same kiln at one operation. The economy of this process must be evident from the circumstance, that the inflammable part of the coal, which is separated to form it into coke, is the only fuel employed to burn the lime; and as the coke is in many places as valuable as the coal from which it is prepared, the cost, if any, of making lime, must be reduced to the most trifling amount.

In burning lime, some burners prefer peat to coal for the fuel; but that preference has probably arisen from an injudicious management of coal. Mr. Dobson asserts peat to be more economical than coal; that coal, by its excessive heat, causes the limestone to run into solid lumps, which it never does with peat, as it keeps them in an open state, and admits the air freely; that the process of burning goes on more slowly with coal, and does not produce half the quantity of lime.

This inconsistency requires no comment; nevertheless, peat is a very useful fuel for the purpose, and an excellent substitute for coal, where the latter is scarcer or dearer. All kinds of lime exposed to the air recover nearly their original weight, except chalk-lime, which, although long exposed, never recovers more than seven-eighths of its original weight. Some limestones, as Portland-stone, yield a very white lime; others, as chalk and roe-stone, a lime with

a yellowish cast; the latter is best adapted for mixing with tarras, puzzolana, or Parker's cement, for buildings under water. It has long been said by lime-burners, that if lime-stone be imperfectly burned in the first instance, no further exposure of it to the fire will produce quick-lime. This assertion, which it was supposed was the offspring of ignorance, has been confirmed by M. Vicat, in a valuable treatise lately published by him on mortar and cements. Such lime, which is technically termed dead lime, does not slake with water, but upon being ground and made into a paste with water, differs from common mortar by setting under water.

KILOMETRE, a thousand metres. In the French system of measures, the metre is the unit, and is equivalent to 3.2808992 English feet. The kilometre is about five-eighths of our statute mile.

KING-POST, or CROWN-POST. *See* CROWN-POST.

KIOSK, a word applied in Turkey to a kind of open pavilion, or summer-house, supported by pillars.

KIRB-PLATE. *See* CURB-PLATE.

KIRB-ROOF. *See* CURB-ROOF.

KITCHEN (Welsh, *kegin*) the cooking-room, an apartment used for the preparation of food, and furnished with suitable accommodations and utensils for that purpose, of which the following are some of the principal.

A range of grating; a smoke-jack in the chimney, to turn the spits for roasting; a large screen to stand before the fire, to keep off the cold air from the articles roasting, by which means the operation is considerably accelerated. An oven, and also a copper boiler, should be constructed on one side of the fire-place, and on the other side, a large cast-iron plate, fixed horizontally, on which to keep sauce and stew-pans continually boiling with a uniform degree of heat. Several preserving stoves should be fitted up, according to the number of the family; and a table as large as the kitchen will admit of. It would be impossible to enumerate the whole of the articles for culinary purposes; but, besides the above, the kitchen should also be furnished with dressers, having drawers or cupboards under them, put up in every vacant part; it should also have shelves fitted up round the sides, in order to set stew-pans, sauce-pans, &c. out of the way. Adjoining to the kitchen, ought to be a large coal-cellar, for the convenient supply of the fire. The water ought to be conducted to the kitchen by means of pipes, to be drawn off by one or more cocks, as may be wanted. The screen should be made of wood, and lined with tin, and fitted up with shelves, so as to hold the dishes and plates to be made hot for dinner. The copper-boiler is sometimes made double, or divided, and both parts heated by the same fire; each part should be furnished with a water-cock. The kitchen table should not be less than three inches thick. If the windows do not afford a very good light, a sky-light should be placed over the table, with a moveable cap, so as to admit any quantity of air at pleasure.

Modern science has introduced so many improvements in this part of a large establishment, that it would be impossible to describe them. For the perfection of the department comprehended under the simple word *kitchen*, we would recommend our readers to inspect that of the Reform Club, or any similar *cuisine*. It is to be regretted that similar improvements, as far as may be deemed advisable, are not more generally introduced into establishments of a humbler description.

KNEE, a piece of timber cut at an angle, or having grooves to an angle.

KNEE, in hand-railing, a part of the back with a convex curvature; it is the reverse of a *ramp*, which is hollow on the back.

KNIFE, *Drawing*. *See* DRAWING KNIFE.

KNOTTING, a process in painting, for preventing the knots from appearing in the finish.

Knotting is a composition of strong size, mixed with red lead, for the first knotting, which prevents the gum from coming through. The second knotting is a composition of white-lead, red-lead, and oil; but in principal rooms, where the knots happen to be very bad, they are often silvered: which is done by laying on a coat of gold size, and, when properly dry, a silver leaf is placed on them, which is sure to prevent the knots appearing.

The operation of knotting is the first process in painting.

KNUCKLE, of a hinge, the cylindrical part, where the one strap is indented into the other, and revolves upon a pin fixed as an axis, in that of the cylinder. *See* HINGING.

KYANIZING, the term applied to the process of preserving timber and other substances from dry rot, invented by Mr. Kyan. Processes of a similar description, and for similar purposes, but differing in the chemical agents employed, have also been patented by Sir William Burnett and others, and called from the respective inventors, Burnettizing, Payanizing, Bethellizing, &c.

Kyan's preparation consists in immersing the substance to be preserved in a solution of corrosive sublimate, which is said to neutralize the primary element of fermentation, and render the fibre of the wood indestructible. The principal advantage, however, claimed for the process, is, that it seasons the timber in so short a time; what, in ordinary circumstances, occupies two or three years, being, by means of Kyanizing, effected in as many months. It is also said to protect the wood from the ravages of insects. We desire to offer no opinion on the comparative merits of these several methods of effecting the same objects. All have been in turn lauded and decried, as all have been in turn used and condemned. They are used extensively in railway sleepers and other engineering works, which, from their exposure, are very liable to premature decay.

It is generally understood, however, among practical men, that timber, though prepared by any of these processes, cannot be depended upon for a certainty to resist the combined effects of moisture and great heat.

L.

LAB LAB

LABEL, an ornament placed over an aperture, in the castellated style of building, consisting of a horizontal part over the head, with two parts returning downwards at a right angle, one on each side of the aperture: sometimes these are terminated at the bottom with a bead, but most frequently return again at a right angle outwards, and, consequently, parallel to the part over the head.

LABOUR, in measuring, the value put on a piece of work, in consideration only of the time required to perform it.

LABRUM, a vase or basin placed in the caldarium of the ancient baths, to contain hot water for persons who had used the vapour bath.

LABURNUM, a well-known tree; the wood of the tree-laburnum is much prized by cabinet-makers and turners.

LABYRINTH, (Greek, λαβυρινθος) among the ancients, a large and intricate edifice cut into various isles and meanders running into each other, so as to render it difficult to get out.

Four celebrated labyrinths were noted by the ancients, and by Pliny ranked amongst the wonders of the world: viz., the Cretan, the Egyptian, the Lemnian, and the Italian. That of Crete is the most famed; it was built, as Diodorus Siculus conjectures, and Pliny positively asserts, by Dædalus, by command of king Minos, who kept the Minotaur shut up in it, on the model of that of Egypt, but on a less scale; but both affirm, that in their time it no longer existed, having been either destroyed by time, or purposely demolished. It was from this labyrinth that Theseus is said to have made his escape by means of Ariadne's clue.

Diodorus Siculus and Pliny represent this labyrinth as having been a large edifice; while others have considered it as merely a cavern hollowed in the rock, and full of winding passages. "If the labyrinth of Crete," says the Abbé Barthelemi, "had been constructed by Dædalus under the order of Minos, whence is it that we find no mention of it either by Homer, who more than once speaks of that prince, and of Crete, or by Herodotus, who describes that of Egypt, after having said that the monuments of the Egyptians are much superior to those of the Greeks; or by the more ancient geographers; or by any of the writers of the ages in which Greece flourished? This work was attributed to Dædalus, whose name," says our author, "is sufficient to discredit a tradition. His name, like that of Hercules, had become the resource of ignorance, whenever it turned its eyes on the early ages. All great labours, all works which required more strength than ingenuity, were attributed to Hercules; and all those which had relation to the arts, and required a certain degree of intelligence in the execution, were ascribed to Dædalus." According to Diodorus and Pliny, no traces of the labyrinth of Crete existed in their time, and the date of its destruction had been forgotten. Yet it is said to have been visited by the disciples of Apollonius of Tyana, who was contemporary with those two authors. The Cretans, therefore, believed that they possessed the labyrinth. "At Nauplia, near the ancient Argos," says Strabo, "are still to be seen vast caverns, in which are constructed labyrinths, that are believed to be the work of the Cyclops;" the meaning of which, as Barthelemi understands him, is, that the labours of men had opened in the rock passages which crossed and returned upon themselves, as in quarries. Such, he says, is the idea we ought to form of the labyrinth of Crete. He then suggests an inquiry, whether there were several labyrinths in that island? Ancient authors speak only of one, which most of them place at Cnossus, and some few at Gortyna. Belon and Tournefort describe a cavern situated at the foot of mount Ida, on the south side of the mountain, at a small distance from Gortyna: which, according to the former, was a quarry, and, according to the latter, the ancient labyrinth. Besides this, another is supposed to have been situated at Cnossus, and, in proof of the fact, it is alleged, that the coins of that city represent the plan of it. The place where the labyrinth of Crete was situated, according to Tournefort, was, as Barthelemi supposes, one league distant from Gortyna; and, according to Strabo, it was distant from Cnossus six or seven leagues; with respect to which our author concludes, that the territory of the latter city extended to the vicinity of the former. In reply to the inquiry, what was the use of the caverns, denominated labyrinths, Barthelemi imagines, that they were first excavated in part by nature; that in some places stones were extracted from them for building cities, and that, in more ancient times, they served for an habitation or asylum to the inhabitants of a district exposed to frequent incursions. According to Diodorus Siculus, the most ancient Cretans dwelt in the caves of mount Ida. The people, when inquiries were made on the spot, said, that their labyrinth was originally a prison. It might indeed have been applied to this use; but it is scarcely credible that, for preventing the escape of a few unhappy wretches, such immense labours would have been undertaken.

In Walpole's collection of *Travels in various Countries of the East*, there is an account by Mr. Cockerell of an excursion from the town of Candia to a curious excavation in a mountain about three miles from Agio Deka, a village near the site of Gortys, and 20 miles inland from Candia, which the inhabitants call by the name of the labyrinth. It is a very intricate maze, cut through a freestone rock; many of the passages are very low and narrow, but the principal way is about 8 feet wide, and as many in height. There are several square chambers at the ends of some of the passages, and piers have been left in the middle to support the superincumbent rock. Mr. Cockerell has explored all the excavation that was accessible, of which he gives a plan; it is in its whole length, including the windings, about three-quarters of a mile, but this is evidently only part of the whole, as many of the passages are stopped up in consequence of the falling in of the rock. Some have supposed this to have been the labyrinth of Minos.

The labyrinth of Egypt, according to Pliny, was the oldest of all; and was subsisting in his time, after having stood, according to tradition, as he says, 4,600 years. He says it was built by king Petesucus, or Tithoës; but Herodotus makes it the work of several kings: it stood on the southern bank of the lake Mœris, near the town of Crocodiles, or Arsinoe, and consisted of twelve large contiguous palaces, in which the twelve kings of Egypt assembled to transact affairs of state and religion, containing 3,000 apartments, 1,500 of which were under ground.

This structure seems to have been designed as a pantheon, or universal temple of all the Egyptian deities, which were separately worshipped in the provinces. It was also the place of the general assembly of the magistracy of the whole nation; for those of all the provinces or nomes met here to feast and sacrifice, and to judge causes of great consequence. For this reason, every nome had a hall or palace appropriated to it; the whole edifice containing, according to Herodotus, 12; Egypt being then divided into so many kingdoms. Pliny makes the number of these palaces 16, and Strabo makes them 27. All the halls were vaulted, and had an equal number of doors opposite to one another, six opening to the north, and six to the south, all encompassed by the same wall. The exits, by various passages and innumerable returns, afforded to Herodotus a thousand occasions of wonder. The roofs and walls within were encrusted with marble, and adorned with sculptured figures. The halls were surrounded with pillars of white stone finely polished; and at the angle, where the labyrinth ended, stood the pyramid, which Strabo asserts to be the sepulchre of the prince who built the labyrinth. According to the description of Pliny and Strabo, this edifice stood in the midst of an immense square, surrounded with buildings at a great distance. The porch was of Parian marble, and all the other pillars of marble of Syene; within were the temples of their several deities, and galleries, to which was an ascent of 90 steps,

adorned with many columns of porphyry, images of their gods, and statues of their kings, of a colossal size: the whole edifice was constructed of stone, the floors being laid with vast flags, and the roof appearing like a canopy of stone: the passages met, and crossed each other with such intricacy, that it was impossible for a stranger to find his way, either in or out, without a guide; and several of the apartments were so contrived, that on opening of the doors, there was heard within a terrible noise of thunder. Although the Arabs, since the days of Pliny, helped to ruin this structure, yet a considerable part of it is still standing. The people of the country call it the palace of Charon.

Strabo, Diodorus Siculus, Pliny, and Mela, speak of this monument with the same admiration as Herodotus; but not one of them says it was constructed to bewilder those who attempted to pass through it; though it is manifest, that, without a guide, they would have been in danger of losing their way. The Abbé Barthelemi suggests, that this danger introduced a new term into the Greek language. The word *labyrinth*, taken in the literal sense, signifies a circumscribed space, intersected by a number of passages, some of which cross each other in every direction, like those in quarries and mines, and others make larger or smaller circuits round the place from which they depart, like the spiral lines that are visible on certain shells. Hence it has been applied, in a figurative sense, to obscure and captious questions, to indirect and ambiguous answers, and to those discussions, which, after long digressions, bring us back to the point from which we set out.

The labyrinth of Lemnos is mentioned by Pliny as having existed on the island, like those of Egypt and Crete. It was said to have been supported by 150 columns of wonderful beauty, and to have gates so well poised, that a child could throw them open. Pliny adds, that it was constructed by three native architects, and that some remains of it were still in existence.

The labyrinth of Italy was built, it is said, by Porsenna, king of Etruria, for his tomb, but the accounts of it partake so much of the fabulous, that it has been doubted by many authors whether it ever existed at all.

Labyrinth Fret, a fret with many turnings, in the form of a labyrinth; one of the most ancient ornaments in the world.

LACHRYMATORY, the name of a small glass or bottle, like a phial, sometimes found in the sepulchres of the ancients, in which it was supposed the tears of the deceased person's friends were collected and preserved.

LACONICUM, a recess in the caldarium, in which the labrum for the ablutions of those using the vapour-bath was placed. Some writers apply the term merely to the cupola in the floor of the hot-bath, in which the flame from the hypocaust played, to heat the apartment.

LACUNARIS, Lacunaria or Lacunars, in architecture, the panels of coffers formed on the ceilings of apartments, and sometimes on the soffits of the corona of the Ionic, Corinthian, and Composite orders.

In the temple of Minerva at Athens, the lacunars are placed immediately above the frieze within the portico, and formed with a single recess, having an ovolo at the top, which moulding terminates the vertical plane sides, and the horizontal heads of the lacunars. The lacunars are not square, but longer in the longitudinal than in the transverse direction of the building.

In this they are formed in one recess, with an ovolo at the top of the recess, or the farthest extremity of the sides. The lacunars are longer from front to rear of the portico, than in the transverse direction of the building.

In the temple of Theseus at Athens, the lacunars are formed above the frieze, in two rows, between large beams which reach from the rear to the front of the pronaos: their figures are of a square horizontal section, and have only a single recess upwards, with an ovolo above it. The side of the square of each coffer is about one-fifth part of the diameter of the column, and their recess upwards of half the side of their square. The distance between the beams is equal to the breadth of the antæ at the bottom, or nearly equal to the diameter of the columns. The beams are not regulated by the columns, but placed at equidistant intervals, to receive the two rows of lacunars, or coffers. Within the temple or cella, the beams reach transversely, from side to side; but without, and under the soffit of the pronaos, they extend longitudinally from the front to the rear of the pronaos, and the lacunars in the same direction.

In the soffit of the temple of Pandrosus at Athens, the lacunars are formed immediately above the architrave, each into three recesses, with an ovolo at the bottom of each, nearly as broad as the perpendicular surface. The whole depth of the recess is nearly half the side of the square of its lower part. Each part diminishes gradually in breadth in a sloping straight line, till the side of the square of the upper part is so contracted as to be only half that of the lower. Each succeeding third part diminishes regularly in altitude, so that, accounting the bottom the first, the altitude of the second, or the one next above, is something less, and the third about the same quantity less than the second. Each ovolo is something less in height than the vertical surface below it, and has the same ratio to its respective surface.

The cella of the temple of Vesta at Rome is surrounded with a circular colonnade. The ceiling of the portico has a double row of lacunars, being two in the breadth of the portico. The lacunars approach as nearly to a square as is consistent with their diminution, formed by radiations towards the centre of the building, and are constructed in two recesses. The greatest breadth of the outside lacunar is about nine-thirteenths of the diameter of the columns. The whole depth of the recess upwards is about one-seventh of a diameter. The radiating sides are in vertical planes, and the other two sides of each are vertical cylindric concentric surfaces. The greatest breadth of the upper recess is about two-thirds of the lower. The hollow of this recess is occupied by a rose of a circular form. The recess or cradle vaults of the temple of Peace at Rome are arched, and enriched with octagonal lacunars, each formed in three recesses, which diminish in their margins as they recede upwards. Between the octagonal lacunars are others of a square form in a diagonal position. The ceiling of the middle of the chapel of the said temple, is comparted with hexagonal and rhomboidal lacunars.

The lacunars of the arch of Titus at Rome are square, the side of each being about three-quarters of the diameter of the column.

LADDER, a well-known contrivance used in building operations &c., it is formed of two long side pieces of wood, connected by rounds or treads, forming the steps by which the workmen ascend.

LADY-CHAPEL, a name invented by modern architects and virtuosi, to signify the chapel which is generally found in our ancient cathedrals behind the screen of the high altar. It is denominated from its being generally dedicated to the Virgin Mary, called *Our Lady*.

LANCET ARCH, the same as pointed arch.

Lancet Window, that of which the head is a lancet arch; but the term is more generally applied to those windows which are long and narrow, with lancet arches.

LANDING, the first part of a floor at the head of a stair, also a resting place in a series of flights of steps.

LANTERN, in architecture, a turret raised above the roof with windows round the sides, in order to light the apartment below. Lanterns are much more convenient than skylights; for as the surface of the glass stands vertical, they are not so liable to be broken, nor so subject to the rattling noise of heavy rains and hail. The word lantern is also applied to light erections at the top of towers or domes, as at Boston church, Lincolnshire, and St. Paul's, London.

LANTERN, is also used for a square cage of timber, with glass in it, placed over the ridge of a corridor, or a gallery between two rows of shops, to illuminate them.

LAP, the junction of two bodies where they mutually cover each other.

LARDER, or SAFE, a place in which undressed meat is kept for the use of a family.

It ought to be so large, as to hold a quantity proportioned to the number of the family, and should be well ventilated through the roof, so as to keep a continued circulation of air; the light must be from windows in the wall, which ought to have a northern aspect. The roof ought to be double, so as to contain a cavity for air, in order to preclude the heat of the sun, and the whole building constructed of wood. The windows should be wired, or of perforated zinc, rather than glazed, and the interstices so small as not to admit of any flies. In order to prevent the sun from getting in, the exterior roof should over-hang the safe, so as to keep off the sun's rays, which will only be in the morning and afternoon of the day. If a northern aspect cannot be obtained for light, other means must be employed to preclude the sun's rays. The floor should be elevated above the ground, to prevent dampness, say two or three feet, as may be found convenient; and the safe here spoken of should not adjoin any other building, since its use is to keep the meat cool. The safe should be fitted up with a row of shelves and several rows of hooks, in the manner that butchers hang up joints of meat, &c. The shelves are necessary to lay the meat on when wanted. The hooks must be fastened to beams, and not to the sides of the safe; and the beams should be placed so high as to keep the meat above the head of any person.

LARMIER (from the French) signifying tears; the word is of the same import as CORONA, which see.

LATCH, the catch for holding a door fast.

LATH, a slip of wood used in plastering, tiling, and slating. These are what Festus calls *ambrices;* in other Latin writers they are denominated *templa;* and by Gregory of Tours, *ligaturæ.*

In plastering, the narrower the laths are, the better they are for the purpose, so that they be of sufficient breadth to hold the nails, as the more the number of interstices is increased, the more readily will the lime or stuff hang; and the thicker they are, the better will they be adapted to resist violence; but then they would be much more expensive. The laths are generally made of fir, in three, four, and five feet lengths, but may be reduced to the standard of five feet. Laths are single or double; the latter are generally about three-eighths of an inch thick, and the former barely one quarter, and about an inch broad. Laths are sold in bundles; the three-feet are eight score to the bundle, four-feet, six score, and the five-feet, five score.

The lath for plain tiling is the same as that used in plastering. Laths are also distinguished into *heart* and *sap laths;* the former should always be used in plain tiling, and the latter, of an inferior quality, are most frequently used by the plasterer. Heart-of-oak laths, by the statute Edw. III. should be one inch in breadth, and half an inch in thickness; but now, though their breadth be an inch, their thickness is seldom more than one quarter of an inch; so that two, as they are now made, are but equal to one. According to the same statute, pantile laths are nine or ten feet long, three-quarters of an inch thick, and one and a half inch broad, and should be made of the best yellow deal: the bundle consists of twelve such laths. A square of plain tiling will require a bundle of laths, more or less, according to the pitch. The distance of laying laths one from another is various, differing more in some places than in others; but three and a half, or four inches, are usual distances, with a counter-lath between rafter and rafter; but if the rafters stand at wide intervals, two counter-laths will be necessary. Laths are employed for various other purposes besides plastering and tiling, as in filleting for sustaining the ends of boards; in naked flooring and roofing, for furring up the surfaces; and in every kind of small work, where the dimensions of the parts do not exceed the scantling of laths.

In lathing for plastering, it is too frequent a custom to lap the ends of the laths upon each other, where they terminate upon a quarter or batten, to save the trouble of cutting them; but though this practice saves a row of nails, it leaves only a quarter of an inch for plaster, and if the laths are very crooked, as they frequently are, there will be no space whatever left to straighten the plaster; the finished surface must, therefore, be rounded, contrary to the intention and to the good effect of the work; but if the ends are to be laid upon each other, they should be thinned at the lapping out to nothing at the extremity, or otherwise they should be cut to exact lengths.

Laths should be as evenly split as possible; those that are very crooked should not be used, or the crooked part should be cut out; and such as have a short concavity on the one side, and a convexity on the other, not very prominent, should be placed with the concave side outwards. The following is the method of splitting laths: the lath-cleavers having cut their timber into lengths, they cleave each piece with wedges into eight, twelve or sixteen pieces, according to the scantling of the timber: the pieces thus cloven are called *bolts;* then in the direction of the felt-grain, with their dowl-axe, into sizes for the breadth of the laths: this operation they call *felting;* and, lastly with their chit, they cleave them into thicknesses by the quarter-grain.

In the United States of America, machinery has been employed for rending as well as for sawing out laths: there is nothing original in the latter operation, but there is apparently something worthy of notice by our countrymen in the annexed report of American patents, which we extract from the *Franklin Journal* of Philadelphia.

In Rice's machine, "a stock is fixed in a frame, in which it slides freely backward and forward; it is moved by a cog-wheel, which works in cogs on one side of the stock, in the manner of a rack and pinion. A knife, is fixed upon the stock, and the timber to be cut into laths, &c., is fixed in a frame, and is made to bear against the stock and the lath is cut by the traversing motion of the stock. The knife, it is said, many have a double edge, so as to cut a lath by the forward and backward motion."

Lynch's machine "consists of a long plank, which operates as a plane stock; this plank is made to slide upon its edge between upright standards upon a firm platform; a wide iron like a plane-iron, is fixed so as to cut on one face of this plank much in the manner of the cutters of some single machines; the throat of the plane, if we may so call it, has other cutters standing at right angles with the first cutter, and at such distances apart as to reduce the laths to a proper

width. The cutter plank is made to traverse by means of a pitman at one end, operated upon by any suitable power.

LATH-BRICKS are bricks made much longer than the ordinary sort, and used instead of laths for drying malt upon, for which purpose they are extremely convenient, as not being liable to catch fire, and retaining the heat much longer than those made of wood, so that a very small fire is sufficient after they are once heated.

LATHE, a very useful engine for the turning of wood, ivory, metals, and other materials. The invention of the lathe is very ancient. Diodorus Siculus says, the first who used it was a grandson of Dædalus, named Talus. Pliny ascribes it to Theodore of Samos, and mentions one Thericles who rendered himself very famous by his dexterity in managing the lathe. With this instrument the ancients turned all kinds of vases, many whereof they enriched with figures and ornaments in basso relievo. The lathe is composed of two wooden cheeks or sides, parallel to the horizon, having a groove or opening between; perpendicular to these are two other pieces called puppets, made to slide between the cheeks, and to be fixed down to any point at pleasure. These have two points, between which the piece to be turned is sustained; the piece is turned round, backwards and forwards, by means of a string put round it, and fastened close to the end of a pliable pole, and underneath to a treadle or board, moved with the foot. There is also a rest which bears up the tool, and keeps it steady.

LATTICE, from lath; wood or iron work made by crossing bars, rods, or laths, in such a manner as to form open chequered or reticulated work.

LATTICE-WINDOWS are those made of bars or strips of iron which cross one another like net-work: windows of lattice or lath were once general in England.

LAUNDRY, a large room, wherein linen after washing is mangled and ironed (and sometimes dried, if there is not a drying-room for the purpose.) The chief and most important utensil in a laundry, is a good stove to heat the irons, likewise dry the linen, besides which there should also be a large range of grating, to air the linen after being ironed or mangled. The stove ought to stand nearly in the middle of the room, and have a long iron pipe for the smoke to ascend, which should be carried several times backward and forward, and at length terminate in the flue of the chimney near the ceiling, by which means it will throw a considerable heat into the room. As it is a known property of heat to ascend, large racks or horses are made so as to be drawn up by pulleys horizontally to the ceiling, where the linen will dry very soon. There should be a mangle, a mangling table, and a large board or dresser fixed to the window side of the room, which ought to be fitted up underneath with large drawers and cupboards for holding linen in, after finished. There should be an adjoining room for the laundry-maids to sleep in. There ought to be a place to hold a sufficient quantity of coals to serve for a day or two, which is filled from the coal-house, near the wash-house; there ought also to be a place fitted up for the maids to wash their hands.

LAVATORY, a cistern or conduit attached to the cloisters in monastic establishments, and used by the monks and other members of the communities for their ablutions; several of these lavatories are still in existence, as in the cloisters of Norwich, Wells, Gloucester and other cathedrals. The name lavatory, or *lavadero*, is also given to certain places in Peru and Chili, where gold is obtained from the earth by washing.

LAVER. The basin or vessel, placed in the court of the Jewish tabernacle, where the officiating priests washed their hands, and feet, and cleansed the entrails of victims.

LAWN, an open space of short-grass ground, in the front of a residence, or in a garden, park, or other pleasure-ground. These, when extended in the principal fronts of habitations, add considerably to the neatness and grandeur of their appearance, by laying them open, and admitting more extensive prospects. Where there is a sufficient scope of ground, they should be as large as the nature of the situation will admit, always being planned in the most conspicuous parts immediately joining the houses, and extended outward as far as convenient, allowing width in proportion; having each side or verge bounded by elegant shrubbery compartments in a varied order, separated in some parts by intervening spaces of grass-ground, of varied dimensions, and serpentine gravel-walks, gently winding between and through the plantations, for occasional shady, sheltered, and private walking: or similar walks carried along the fronts of the boundary plantations, and immediately joining the lawns, for more open and airy walking in; and in some concave sweeps of the plantations there may be recesses and open spaces both of grass and gravel, of different forms and dimensions, made as places of retirement, shade, &c.

Though the usual situations of lawns are those just mentioned; yet if the nature of the ground admit, or in cases where there is a good scope of ground, they may be continued more or less each way; but always the most considerably on the principal fronts, which, if they be to the south, or any of the southerly points, are the most desirable for the purpose.

With respect to the dimensions, they may be from a quarter of an acre, or less, to six or eight acres, or more, according to the extent and situation of the ground. Sometimes lawns are entended over *ha-has*, to ten, twenty, or even to fifty or sixty acres, or more. But in these cases they are not kept mown, but eaten down by live stock.

The form must be directed by the nature of the situation; but it is commonly oblong, square, oval, or circular. But in whatever figure they are designed, they should widen gradually from the house outward to the farthest extremity, to have the greater advantage of prospect; and by having that part of them within the limits of the pleasure-ground, bounded on each side by plantations of ornamental trees and shrubs, they may be continued gradually near towards each wing of the habitation, in order that the inhabitants may be sooner in the walks of the plantations, under shade, shelter, and retirement. The terminations at the farther ends may be either by *ha-has* to extend the prospect, or by a shrubbery or plantation of stately trees, arranged in sweeps and concave curves. But where they extend towards any great road, or distant agreeable prospect, it is more in character to have the utmost verge open, so as to admit of a grand view from and to the main residence.

The side-boundary verges should have the plantations rurally formed, airy and elegant, by being planted with different sorts of the most ornamental trees and shrubs, not in one continued close plantation, but in distinct separated compartments and clumps, varied larger or smaller, and differently formed, in a somewhat natural imitation, being sometimes separated and detached, less or more, by intervening breaks, and open spaces of short grass, communicating both with the lawns and interior districts; and generally varied in moderate sweeps and curves, especially towards the lawns, to avoid stiff, formal appearances, both in the figure of the lawns and plantations. In planting the trees and shrubs, which should be both of the deciduous and evergreen kinds, where intended to plant in distinct clumps, either introduce the deciduous and evergreens alternately in separate parts, or have some of both interspersed in assemblage; in either method, placing the lower growth of shrubs towards the front, and the taller backwards, in proportion to their several

statures, so as to exhibit a regular gradation of height, that the different sorts may appear conspicuous from the main lawns. They may be continued backwards to a considerable depth, being backed with trees and shrubs of more lofty growth. The internal parts of the plantations may have gravel or sand walks, some shady, others open ; with here and there some spacious short-grass openings, of different dimensions and forms.

It is seldom that extensive lawns in parks or paddocks, &c. have any boundary plantations close to what may be considered as a continuation of them beyond the pleasure-ground, but they are sometimes dotted with noble trees, dispersed in various parts, at great distances, so as not to obstruct the view; some placed singly, others in groups, by twos, threes, fives, &c. and some placed irregularly, in triangles, sweeps, straight lines, and other different figures, to cause the greater variety and effect, each group being diversified with different sorts of trees, all suffered to take their natural growth. Where small, these kinds of openings should always be kept perfectly neat, by being often poled, rolled, and mown ; but where they are of larger extent, this is scarcely ever the case.

LAYER. *See* COURSE.

LAZARETTO, or, LAZAR-HOUSE, a public building, in manner of an hospital, for the reception of poor sick : or in some countries, an edifice, or sometimes a ship, appointed for persons coming from places suspected of the plague, to perform quarantine.

The name "Lazaretto," is derived from St. Lazarus, who, in the Romish calendar, is patron of lepers. Leprosy during the middle ages was a common disease in Italy and other parts of Europe, and the lepers, or persons afflicted with it, were called lazzari. Hence the term lazaretto applied to the hospitals where such persons were confined. In England similar receptacles were often called lazar-houses, or houses of lepers.

John Howard, the distinguished philanthropist, whose services in the cause of humanity can never be forgotten, was the first who drew public attention to the state of the lazarettos on the continent. In the year 1785, he personally inspected most of these institutions, and in his work entitled "An account of the principal Lazarettos in Europe," has given a complete exposition of the plans of the buildings, and their chief regulations. The result of this inspection was the adoption of many of the valuable suggestions made by Howard : and many a weary traveller, suffering under the annoyances of the quarantine system, has had reason to bless the name of the man who did so much to alleviate them. Although some improvements have been made since Howard's time, the main features of these buildings remain nearly the same. His description of those he visited, therefore, may, even at the present day, be considered a faithful one, and interesting to those who, "living at home at ease," have little idea of what it is to be in quarantine. The first lazaretto he inspected was that at Marseilles, which is situated on an elevated rock near the city, at the end of the bay, fronting the south-west, and commanding the entrance of the harbour. It is a spacious building, and its situation renders it very commodious for the purposes of trade. Within the lazaretto is the governor's house, a chapel, in which divine service is generally performed, and a tavern, from which persons under quarantine may be supplied with necessaries. In order to prevent any communication not allowed by the regulations of the establishment, there is a double wall round the lazaretto ; and at the gate there is a bell for calling any person within this enclosure ; and by the number and other modifications of the strokes, every individual knows when he is called. At Genoa the lazaretto is situated on the sea-shore, near the city, detached from other buildings, and encompassed by a double wall. Another lazaretto, belonging to the Genoese, stands on a rising ground at Varignano, near the gulf of Spezia. At Leghorn there are three lazarettos. At Naples, the lazaretto is very small, and is situated on a peninsula near the city. Vessels having *clean* bills of health, lie at the entrance of the port, near the health-office, but those with foul bills, are required to perform their quarantine at the lazaretto. At Messina, the lazaretto stands on an island near the city. The health-office at Zante, is in the city, at the water-side. The old lazaretto is distant about half a mile from the city, and situated on a rising ground near the sea. There is another, called the new lazaretto, which is appropriated to a numerous body of peasants, who pass over to the Morea, to work in harvest time ; on their return, they perform here a seven days' quarantine : and other persons perform fourteen days quarantine in the old lazaretto. The lazaretto at Corfu is finely situated on a rock surrounded with water, about a league from the city. The lazaretto of Castel-Nuova, in Dalmatia, is on the shore about two miles from the city ; at the back of it there is a delightful hill, which belongs to a convent of friars. Persons in quarantine, after a few days, are allowed to walk there, and divert themselves with shooting, &c.

In order to obtain the most complete and satisfactory information, by performing the strictest quarantine, Howard determined to go to Smyrna, and there to take his passage to Venice in a ship with a foul bill. He was thus enabled to give a particular account of his reception and accommodation in the new lazaretto of this city, which is chiefly assigned to Turks and soldiers, and the crews of those ships which have the plague on board ; and this he thought the more necessary, as the rules and tariffs of the other lazarettos in Europe have been evidently formed from those established at Venice. The city of Venice has two lazarettos, appropriated to the expurgation of merchandise susceptible of infection, coming from suspected parts and for the accommodation of passengers in performing quarantine, as also for the reception of persons and effects infected in the unhappy times of pestilence. The old lazaretto is two miles, and the new about five miles, distant from the city, both on little islands, separated from all communication, not only by broad canals surrounding them, but also by high walls ; they are of large extent, being about 400 geometrical paces in circumference. Of these Mr. Howard has given a particular description; with an account of the regulations and mode of government to which they are subject, and a plan of the old lazaretto. At Trieste there are two lazarettos ; one new, but both clean, and a contrast to those which he had seen at Venice. Of the new one he has given a plan. It is surrounded, at the distance of about twenty yards, by a double wall, within which are separate burying places for Roman Catholics, Greeks, and Protestants. Howard closes his account of the principal lazarettos in Europe, with the outlines of a proper lazaretto, and an engraved sketch of a plan for its construction. He has likewise subjoined, in minute detail, various pertinent remarks respecting quarantine and lazarettos in general.

Within the last few years, however, more enlightened views on the whole subject of the quarantine system have begun to prevail, and are gradually obtaining support. Eminent medical authorities, both in this country and on the Continent, have expressed the strongest opinions, as to its total inefficacy in preventing the introduction of disease ; while on the other hand the injury done by it to the interests of commerce, injury which cannot be adequately estimated, is earnestly and justly insisted upon by the merchants of all nations. It may be hoped, then, that these considerations

may have their proper effect with those in authority, and that laws so oppressive and so injurious may shortly be abolished. A greater attention to sanitary regulations will go far to prevent the generation of disease at home ; and then, even without quarantine laws, we need have little apprehension of contagion from abroad.

LEAD, (from the Saxon *lœd.*) The colour of lead is of a bluish-white ; when tarnished, it becomes yellowish-white, then bluish, and at last bluish-black. Lustre when untarnished, 3 ; hardness, 5 ; and specific gravity, somewhere between 11 and 12. According to Brisson, it was 11·352 : and a specimen tried by Gellert, which was found at Freyburg, was estimated at 11·445. Next to gold, platina, and mercury, it is the heaviest metal, being upwards of eleven times heavier than an equal bulk of water. The heaviest is reckoned the best. It stains paper and the fingers. Next to tin, it is the most fusible of all the metals. It is soluble in most of the acids, though more readily so in the nitrous diluted than the others. By exposure to the moist atmosphere, it rusts or oxides. It is malleable and unelastic, and its oxide is easily fusible into a transparent yellow glass

Lead is most used in building, particularly for coverings, gutters, pipes, and in glass windows. For which uses, it is either cast into sheets in a mould or milled ; which last, some have pretended, is the least serviceable, not only on account of its thinness, but also because it is so exceedingly stretched in milling and rendered so porous and spongy, that when it comes to lie in the hot sun, it is apt to shrink and crack, and consequently will not keep out the water. Others have preferred the milled lead, or flatted metal, to the cast, because it is more equal, smooth, and solid.

The lead used by glaziers is first cast into slender rods, twelve or fourteen inches long, called *canes ;* and these, being afterwards drawn through their vice, come to have a groove on either side for the panes of glass; and this they call *turned* lead.

The method of paling or soldering lead for fitting on of embossed figures, &c., is by laying the part whereon the figure is to be paled, horizontally, and strewing on it some pulverized rosin: under this they place a chafing-dish of coals till such time as the rosin becomes reddish, and rises in pimples ; then the figure is applied, and some soft solder rubbed into the joinings ; when this is done, the figure will be paled on, and as firm as if it had been cast on. For other uses in building, see the article Sheet Lead.

LEAN-TO, a small building with a shed-roof attached to a larger one.

LEAVER. *See* Lever.

Leaver Boards. *See* Lever Boards.

LEAVES, a representation in marble, stone, brass, wood, or other material of natural leaves. *See* Ornament.

LEDGE, a surface on which to support a body in motion or to support a body at rest.

The ledges of a door are the narrow surfaces wrought upon the jams and soffit parallel to the wall, in order to stop the door, so that when the door is shut, the ledges coincide with the surface of the door.

The ledges of a door are therefore one of the sides of the rebate, each rebate having only two sides. In temporary works the ledges of doors are formed by fillets.

LEDGEMENT, the development of a surface, or the surface of a body stretched out on a plane, so that the dimensions of the different sides may easily be ascertained.

LEDGERS, in scaffolding for brick buildings, the horizontal pieces of timber parallel to the wall, fastened to the standards by chords, in order to support the put-logs, on which are laid the boards for working upon.

LEGAL COLUMN. *See* Column.

LEGS, of a right-angled triangle, the two perpendicular sides.

Legs of an hyperbola, the two parts on each side of the vertex.

LENGTH (from the Saxon *leng,*) the greatest extension of a body. In a right prism, the length is the distance between the ends : in a right pyramid, or cone, the length is the distance between the vertex and the base.

LENGTHENING, of timber, is the method of joining several beams, so as to form a long beam of any given length. *See* Scarf.

LESBIUM MARMOR, a name given by the ancients to a species of marble of a bluish white, sometimes used for vases, and other ornamental works, but principally in the walls of public buildings.

LEVEL, a mathematical instrument, used for drawing a line parallel to the horizon and continuing it out at pleasure, and by this means, for finding the true level, or the difference of ascent or descent between any two places, for conveying water, levelling the surface of floors, and for various other purposes in architecture, hydraulics, surveying, &c.

Level, *Carpenter's*, consists of a long rule, straight on its lower edge, about ten or twelve feet in length, with an upright piece fixed to its upper edge, perpendicular to, and in the middle of the length, having its sides in the same plane with those of the rule, and a straight line drawn on one of its sides perpendicular to the straight edge of the rule. This standing piece is generally mortised into the other, and firmly braced on one side, in order to secure it from accidents, and has its upper end kerfed in three places, viz., through the perpendicular line, and on each side. The straight edge of the transverse piece has a hole or notch cut out on the under side, equal on each side of the perpendicular line. A plummet is suspended by a string from the middle kerf at the top of the standing piece, so that, when hanging at full length, it may vibrate freely in the hole or notch. When the straight edge of the level is applied to two distant points, with its two sides placed vertically, if the plummet hangs freely, and coincides with the straight line on the standing piece, the two points are level ; but if not, suppose one of the points to be at the given height, the other point must be lowered or heightened, as the case may require, until the third is brought to a coincidence with the perpendicular line. By two points is meant two surfaces of contact, as two blocks of wood, or chips, or the upper edges of two distant beams.

The use of the level in carpentry, is to lay the upper edges of joints in naked flooring horizontal, by first levelling two beams as remote from each other as the length of the level will allow ; the plummet may then be taken off, and the level be used as a straight edge. In the levelling of joints, it is best to make two remote joints first level in themselves, that is, each throughout its own length, then the two level with each other ; after this, bring one end of the intermediate joists straight with the two which have been levelled ; then the other end in the same manner ; then try the straight edge longitudinally on each intermediate joist, and such as are found to be hollow must be furred up straight.

To adjust the level.—Place it in its vertical situation upon two pins or blocks of wood ; then, if the plummet, hanging freely, settle upon the line on the standing piece, (or, if not, one end being raised, or the other end lowered, to make it do so,) turn the level end for end, and if the plummet fall upon the line, the level is just ; but if not, the bottom edge must be shot straight, and as much taken off the one end as you may think necessary ; then trying the level first one way

and then the other, as before, if a coincidence takes place between the thread and the line, the level is adjusted; but if not, the operation must be repeated till it come true.

The most convenient class of levels is the *spirit level*, called also the *air level*, which is more accurate than any other kind, and is most extensively used. The invention of this instrument has been ascribed to M. Thevenot. Others have attributed this application of a bubble of air to Dr. Hooke. The instrument consists of a cylindrical glass tube filled with spirits of wine, except leaving in it a small bubble of air; its ends being hermetically sealed to keep in the fluid. This bubble, being the lightest of the contents of the tube, will, by the laws of hydrostatics, always run towards that end of the tube which is most elevated; but when the tube is perfectly horizontal, the bubble will have no tendency towards either end. The tube is not strictly cylindrical within side, though it bears that appearance, but is slightly curved, the convex side being upwards, and by this means the bubble will rest in the middle of the tube when it is horizontal, but approaches either end if elevated above the other. The simplest form of a spirit level for fixing any plane truly horizontal, consists of a glass tube of the above description, called a *bubble tube*, fixed into a block of wood, as at A B, *Figure* 1. The lower surface, D E, of the block is made flat; and when the bubble, C, stands between two scratches marked on the glass at *a b*, the line D E is horizontal. The method of making it correct is this: the tube is first fitted into the block, the lower edge, D E, of which is placed on a bench or table as nearly horizontal as can be determined, so that the bubble stands between the scratches *a b*. The level is now reversed, that is, the end D is put where E was at first. In this position, if the bubble stands in the middle, it proves the level to be correct, and the table horizontal; but if it runs to either end of the tube, it shows that end to be too much elevated: suppose it B, for instance; this end of the tube must therefore be let deeper into the wood, or the surface D E rectified to produce the same effect: one-half the error must be compensated by this means, and the other half by rectifying the table or support; for D E, the level, must now be reversed again to verify these corrections; and when they are so made that the bubble stands at *a b*, either way, the level is correct. To illustrate this more plainly, see *Figure* 2, which represents a section of the bubble tube; but, for elucidation, is shown as if curved much more than they are ever made. Suppose the convex or upper surface of the tube to be a segment of a large circle, B C D; from the laws of hydrostatics, it is plain that the bubble of air, being the lightest body in the tube, will certainly occupy the highest point of the circle at C; and the two points, B, D, being equally distant therefrom, will be in the same horizontal line B E D. The larger the radius of the circle D B, so will the level be the more sensible of any deviation from the horizontal, because the bubble will have to traverse a greater distance along the tube, in proportion to any partial elevation of either end.

LEVELLING, the art or act of finding a line parallel to the horizon, at one or more stations, in order to determine the height of one place with respect to another; for the laying grounds even, regulating descents, draining morasses, conducting waters for the irrigation of land, &c.

LEVER, or Leaver (from the French *levier*, formed of the verb *lever*, derived from the Latin, *levare*, "to raise") in mechanics, an inflexible straight bar, supported, in a single point, on a fulcrum, or prop, and used for the raising of weights.

The lever is the first of those called *mechanical powers*, or simple machines, as being, of all others, the most simple; and is chiefly applied to the raising of weights to small heights.

In a lever three things are to be considered: the weight to be raised, or upheld; the power by which it is to be raised, or sustained; and the fulcrum, or prop, by which the lever is supported, or rather on which it moves round, the fulcrum remaining fixed.

Levers are of three kinds: sometimes the fulcrum, or centre of motion, is placed between the weight and the power. This is called a *lever of the first kind*, or *vectis heterodromus;* to which may be reduced scissors, pincers, snuffers, &c.: sometimes the weight is between the fulcrum and the power, which is called a *lever of the second kind;* such are the oars and rudder of a boat, the masts of ships, cutting knives fixed at one end, and doors whose hinges are as the fixed point: and sometimes the power acts between the weight and the fulcrum, which is the *lever of the third kind;* such is a ladder lifted by the middle to rear it up against a wall: these two are called *vectes homodromi.*

In this last, the power must exceed the weight in proportion as its distance from the centre of motion is less than the distance of the centre from the weight. And as the first two kinds of lever serve for producing a slow motion by a swift one, so the last serves for producing a swift motion of the weight by a slow motion of the power. It is by this kind of lever that the muscular motions of animals are performed, the muscles being inserted much nearer to the centre of motion than the point where the centre of gravity of the weight to be raised is applied; so that the power of the muscle is many times greater than the weight which it is able to sustain. Though this may appear at first a disadvantage to animals, because it makes their strength less; it is, however, the effect of excellent contrivance; for if the power were, in this case, applied at a greater distance than the weight, the figure of animals would be not only awkward and ugly, but altogether unfit for motion; as Borelli has shown in his treatise *De Motu Animalium.*

The knowledge of the properties of the lever is of the utmost use in ascertaining the laws of the resistance of timber; we shall therefore begin with the first principles of motion, from which the properties of the lever are obtained; and also the principles of the centre of gravity of one, or of a system of bodies.

1. Force is the power exerted on a body to move it.

2. Direction of motion or tendency is the effort which one body makes to move another towards a given point.

3. Line of direction is the straight line in which a body moves, or has a tendency to move, without having any regard to the point to which it tends.

4. Angle of direction is the angle contained between two lines of direction.

5. When two or more bodies act against each other without any of them being overcome by the rest, this state of quiescence is called *equilibrium.*

6. Opposite directions, or opposite tendencies, are when each of two bodies move, or have a tendency to move, to a different point in the same line of direction.

7. Opposite forces are those that act upon each other in the same line of direction, but have a tendency to contrary points in the line, by which tendency an equilibrium is produced, or otherwise a change of motion.

8. Contrary directions are when two bodies move, or have a tendency to move, in lines parallel to two opposite planes.

Axiom 1.—Every body endeavours to preserve its present state, whether of rest or of moving uniformly in a right line, till it is compelled to change that state by some external force.

Axiom 2.—The alteration of motion either generated or destroyed in a body, is proportional to the force applied, and is made in the direction of that right line in which the force acts.

Axiom 3.—Action and reaction are equal between two bodies in opposite directions.

Axiom 4.—Two equal forces acting against each other, or against a body, in opposite directions, destroy each other's effect.

Axiom 5.—If a body is acted upon by two forces in opposite directions, it is the same thing as if it were only acted upon by one force equal to their difference, in the direction of the greater force.

Axiom 6.—If a body is kept in equilibrio by three or more forces, the sums of the contrary forces, when reduced to parallel directions, are equal.

Axiom 7.—When a right line is drawn in a direction of its length by two forces acting at its extremities, the line may either be flexible or inflexible.

Axiom 8.—When a right line is pressed or pushed by two forces in the direction of its length, and retains its straightness, the right line is inflexible.

Axiom 9.—When a right line is stretched by two forces, the right line draws each of the forces with the same intensity that the forces stretch the line; because action and reaction are equal and contrary.

Axiom 10.—When a right line is pressed by any two forces at its extremities in the direction of the line, it repels the force with the same intensity with which it is pressed by the forces.

Axiom 11.—If two forces act upon a body and keep it in equilibrio, their lines of direction are in the same right line, and the two forces are equal, and have opposite tendencies.

Axiom 12.—A force pulling by a string or flexible line upon one side of a body, has the same effect in moving or in keeping it in equilibrio, as an equal force pushing or pressing on the same line of direction on the other side.

Axiom 13.—A force acting upon a body has the same power in whatever point of the line of direction it is applied.

Axiom 14.—If a line be pressed or drawn by two opposite forces in the direction of the line, all its parts will be equally stretched or compressed.

Postulate.—Grant that the intensities of forces may be represented by right lines, as well as their directions.

Proposition I.—Plate I. *Figure* 1.—If any body, A, be moved by any impulse which would cause it to describe the right line A B, uniformly in a given time; and if the same body, A, be moved by another impulse, which would cause it to describe the right line A D, uniformly in an equal time: these two impulses, acting at the same instant, would carry the body through the diagonal, A C, of a parallelogram A B C D.

For the impulse which is given in the direction A B, will not prevent the body from coming to D C, by the action of the impulse in the direction A D, in an equal time to that in which A D would have been described by the separate impulse: for the same reason the impulse which is given in the direction A D, will not prevent the body from coming to B C, by the action of the impulse in the direction A B, in an equal time to that in which A B would have been described by the separate impulse: therefore, as the body will meet the lines D C and B C at the same time, it will meet in the intersection C; but because the lines A B and A D, are uniformly described in the same time, any two parts, A E and A F, taken from these lines in the ratio of the lines themselves, will also be described in equal times; and because B C is equal to A D, and E G equal to A F; A B : B C : : A E : E G; therefore the body moves in a straight line which is the diagonal of the parallelogram.

Corollary 1.—Hence, if the direction, intensity, and tendency, of any two forces acting upon a solid are given, a single force may be found, which shall be equivalent to the two.

Corollary 2.—Any single force, whose quantity and line of direction are given, may be resolved into two forces, which shall act at a given point in that line, in two given directions.

Proposition II.—Given, the tracts, intensities, and tendencies of two forces making any angle with each other, to find a single force equivalent to them.

Case I. *Figure* 2.—When each of the two given forces have a tendency, from the points A and C towards B, or from B towards A and C. Complete the parallelogram A B C D, and draw the diagonal B D, and it will represent the quantity and direction of the third force, that will be equivalent to A B and C B; and its tendency will be from B towards D, when the extreme forces tend towards B; but towards B when the extreme forces have a tendency from B.

Case II. *Figure* 3.—When the two given forces tend to two different points. Let A B and B C be the two given forces, let the tendency of A B be from B towards A, and that of B C from C towards B; produce either, as A B, to E: make B E equal to A B, and complete the parallelogram B C D E; draw the diagonal B D, and it will be equivalent to B C and B E, or because B E is equal to B A, and both in the same straight line: and since both forces tend to the same point, A, the force B D is equivalent to B A and B C.

It is evident, that though the angles and directions given were the same in both cases, yet the tendency and quantity would be different in each.

Proposition III.—To resolve any force into two others, in any given directions, which shall act against any point of the line of direction of the given force. *Figure* 4.

Let B E be the line of direction of the given force, B the given point, from which the required intensities are to act, and B F, B G their directions. Make B D equal to the intensity of the given force; complete the parallelogram A B C D; then B A is the force acting in the line B F; B C that in the line B G; and their tendencies are contrary to the middle force.

Proposition IV.—If any two forces keep a third in equilibrio, the direction of the third has the same point of concourse, and is in the same plane with the other two, and all the three forces are to each other as the sides and diagonal of a parallelogram formed on their lines of direction, *Figure* 5.

Let A B, B C, be the two forces; complete the parallelogram A B C D; then the force D B is equivalent to A B and B C; but if any force be in equilibrio with D B, it must be equal and opposite; therefore, make B E equal and opposite, and the two forces B D and B E are in equilibrio: take away the force D B, and let its equivalent forces A B and B C counteract B E, then the three forces A B, C B, and B E, are also in equilibrio: because B D and B E are in a straight line, the direction of E B passes through the point B, and is in the same plane with A B and B C; for D B is in that plane: and because B E is equal to B D, the three forces A B, C B, E B, are expressed by the two sides A B and B C, and the diagonal D B of the parallelogram A B C D, formed on their lines of direction.

Corollary 1.—Hence, if any three forces be in equilibrio with each other, they are as the sides of a triangle drawn parallel to their directions.

Corollary 2.—If the directions of any three forces, acting against the same point, keeping it in equilibrio, be given, and one of the intensities; the intensities of the other two may be found.

Proposition V.—The lines of direction of three forces keeping each other in equilibrio, or a solid, and the intensity and tendency of one of them being given; to find the intensity and tendency of the other two.

Case I. *Figure* 4.—When two of the angles formed by the three lines of direction are less than two right angles. Let the three directions be B F, B E, B G, and let the given intensity be in the line B E, and let its tendency be from E towards B. Make B D equal to the given intensity, and complete the parallelogram A B C D. A B is the intensity in its own line of direction B F, its tendency being from B towards F; and B C is the intensity of the force in its line of direction B G, its tendency being from B towards G: for produce E B to H, since the force acting in the line E B presses the point B, then, by *Axiom* 12, it is the same thing, whether the force in the line E B press the point B, or an equal force on the other side of B: in E H draw the point B, and instead of the force pressing the point B by a force at E, let the point B be drawn by a force at H; thus the point B will be drawn by three forces, which are in equilibrio by the last Proposition. Or if the point B had been drawn by a force acting at E, the two forces acting in the lines B F and B G would have pressed these lines, and consequently three forces acting at F, G, H, would be all pressing the point B; it therefore appears, when three forces keep each other in equilibrio, and their lines of direction make two angles less than two right angles, that the force acting in the intermediate line will be contrary to those in the two extreme lines.

Though this example only shows how to find the two extreme forces when the intermediate force is given; yet the intermediate force and one of the extreme forces may as readily be found by having the other extreme force given: because when one of the angles of a parallelogram is given, and the position of a diagonal passing through that angle, it may be described as readily by having either of the sides as the diagonal.

Case II. *Figure* 5.—When any two angles of direction are greater than two right angles.

Let A B, E B, C B, be the three directions, whereof any two angles made by these lines are greater than two right angles, and consequently the remaining one less than two right angles. Let the given force act in E B; produce E B through the opposite angle to D, so as to divide it into two angles; make B D to represent the intensity in E B, then by completing the parallelogram A B C D, as before, B A will represent the intensity in B A, and B C in B C; and as the forces are supposed to act at the points A, E, C, they are either all drawing the point B or all pressing it.

Proposition VI.—Given, the directions of four forces in the same plane, keeping a solid in equilibrio, and one of the intensities, to find the intensities of the other three.

Produce any two directions till they meet each other; also, produce the other two directions till they meet each other; join the two angular points; then by means of the given force, find the other two at the same point: then, because two forces acting at each point of concourse in the same right line must be equal, and have opposite tendencies, the force in this line acting at the other point of concourse will now be given: therefore, find the two remaining intensities in the same manner as at the first point of concourse.

Example I. *Figure* 6.—Let E A, F B, G C, H D, be the direction of the forces that support the body A B C D, and let the given force be in E A. Produce E A, F B, till they meet in I; also produce G C, H D, till they meet in Q. Join I Q, and produce it to P; then let I K represent the given force, and complete the parallelogram I K L M. Make Q P equal to I L, and complete the parallelogram O P Q R; then will I M represent the intensity in F B, O Q in G C, and R Q in H D.

Example II. *Figure* 7.—Let A B D be a lever with three arms, A C, B C, D C, revolvable about C, as a fulcrum, supported in the direction C O; and let forces act at the extremities A, B, D, in given directions, A K, D E, E B, and keep it in equilibrio: it is required to find the proportion of the forces. Produce two of the directions till they meet; also produce the other direction, and that of the prop, till they meet; join the two angular points, and proceed as in Example I., and find the parallelograms H E F G, and K L M N: then L K is the force acting at A, and M K that in the direction of the prop, H E, the force acting at B, and F E that at D. The tendencies of these forces are thus distinguished: let the point B be drawn towards E, then the line E B is in a state of tension; and because the angles H E G and G E F are less than two right angles, the force in the direction E D will also be in a state of tension, and the middle one, E K, in a state of compression. Again, because the angles L K M and M K N are less than two right angles, and because E K is in a state of compression, K A is likewise in a state of compression, and the middle one C K, is in a state of tension; or the post, C O, on the opposite side, is in a state of compression, acting on the other side of G.

It must be observed, when any force acts upon any point of a solid body, that to draw on one side of the point is the same as to press upon the other side, or to press upon one side is the same as to draw upon the opposite; therefore, as the point C is drawn by the force M K, the prop, C O, is compressed by the fulcrum at C. The arms C A, C B, C D, are supposed to be void of weight. If the forces acting at A, B, D, be weights, P, Q, R, going over the pulleys S, T, U, all the lines, A S, B T, D U, will be in a state of tension.

Proposition VII.—Given, the direction of five forces in one plane, keeping a solid in equilibrio, and the intensities and tendencies of two of them, to find the intensities and tendencies of the rest.

Find a force equivalent to the two given forces; then unite this given force with the three remaining ones, and the directions of four forces, with the intensity of one of them, will be given to find the rest, which may be found by the last problem.

Let A B C D F, *Figure* 8, be a lever, with four arms, F A, F B, F C, F D, revolvable about E, and let it be acted upon by five forces, four of which act upon the arms at the points A, B, C, D, in lines of direction A Q, B S, C K, D I, and the other upon the centre at F, in the line of direction F P; then the intensities and tendencies of the two forces acting in the directions C K, and D I, are given; the one from C to K, and the other from I to D. Produce the two directions C K and D I to meet each other at G, and complete the parallelogram G K I H, as in *Case* 2, Problem II., and G H will be the direction and quantity of the force equivalent to G I and G K: then proceed, as in Problem VI., with the given force G H now found, and the three remaining directions, A Q, B S, P F, and complete the parallelograms M N O P and Q R S T; then N P is the quantity that supports the point or axis F in the direction N F, and S R that which supports B in the direction B R.

From this example it appears, that when the direction of any number of forces is given, and all the intensities and tendencies but three, the intensities and directions of these three may be found by compounding any two of the given forces, then uniting the force found with another of the given forces, and again compounding these, and so on until all the given forces are compounded: then proceeding with the last compounded force and the three remaining directions, as in Problem.

Proposition VIII.—If there be two straight lines, A B, B C,

Figure 9, making any angle, A B C, with each other, and if two forces, equal and opposite in the directions A X, C Y, in the same straight line be applied, and three others in the directions A W, B Z, C J, then if the whole be in equilibrio, the directions Z B, A W, C J, will have the same point of concourse, or otherwise they will be parallel. Join A C, cutting Z B produced in T; take any distance, A D, and complete the parallelogram A G D F; make B H equal to A F, and complete the parallelogram B H I K: make C L equal to B K, and C E equal to A D, and complete the parallelogram C M E L; then all the points A, B, C, are in equilibrio by forces proportional to, and in the directions of the sides and diagonals of the respective parallelograms at these points; now there can be no equilibrium unless C J coincide with C M, for no other force but C M, both in direction and quantity, will balance the two given forces C L and C E; suppose therefore that C J coincides with C M, produce the directions A W and C J to meet Z B produced; then if A W and C J do not meet it in the same point, they will meet it in two different points, U and V; for draw O F, R L, N G, S M, parallel to B V, cutting A C at O, R, N, S; also draw H P, K Q, parallel to A C, cutting B V at P and Q; then will A O=H P=K Q=C R, and therefore A N=S C;

now the triangles A B T and A F O are similar,
therefore . . . . . T A : T B : : Q A : O F
likewise in the triangles C T B and C R L. . . . . T B : T C : : R L : R C
therefore . . . . . T A : T C : : R L : O F
but because L R is equal to S M, and O F to N G . . . . . T A : T C : : S M : N G
then again, by similar triangles, A U T, and A G N . . . . T U : T A : : N G : N A
and it has been proved that . . . . . T A : T C : : S M : N G
also by the similar triangles T C V and S C M . . . . . T C : T V : : S C : S M
therefore . . . . . T U : T V : : S C : N A

but because S C and N A are equal; T U is equal to T V, therefore the points U and V coincide; consequently the three directions meet in the same point.

Corollary I.—F O + L R is equal to B I; for the triangle A F O is equal and similar to the triangle H B P equal and similar to the triangle K Q I; and the triangle C L R is equal and similar to the triangle K B Q.

Corollary 2.—If V *a* be made equal to A G, and V *c* to C M, and the parallelogram V *a b c*, be completed, the forces in the directions A W, Z B, and C J, are as V *a*, V *b*, and V *c*, viz., the three parts of a parallelogram in these directions; for draw *a e* and *c d* parallel to A C, meeting V B in *e* and *d*, then will V *e*=G N=O F=B P, and *e b*=V *d*=M S=R L=B Q=P I, therefore B P+P I=V *e*+*e b*; but B P+I P is the force in the direction Z B, consequently the three forces V *a*, V *b*, V *c*, are equal to those that act in A W, Z B, and C J.

Corollary 3.—If the points A and C are joined by an inflexible line, A C, it is evident that the equilibrium will still be maintained, for this line (by the last proposition) acts the same as the two opposite forces in A X and C Y.

Corollary 4.—When A W, B Z, and C J, are parallel, F D will coincide with F O, G A with G N, L E with L R, and C M with S M: now L R : O F : : T A : : T C ; it will therefore be C M : A G : : T A : T C; consequently, the force A G=force C M=force B I.

Corollary 5.—Hence, if the directions of three forces acting in the plane of a triangle, at the angles, be in equilibrio, the three intensities are as the parts of a parallelogram formed on their lines of direction.

Proposition IX.—If three forces acting against the same point be in equilibrio with each other, and if any point F, *Figures* 10 *and* 11, taken in the line of direction of any one of the forces, the other two forces are to each other reciprocally as the distances of their lines of direction from that point.

Let the lines of direction of the three forces be A D, B D, and C D.

Case I. *Figure* 10.—When the point, F, is taken in the line of direction of the middle force. Complete the parallelogram D E F G; draw F H perpendicular to A D, and F I to C D. Then because the opposite angles D E F and D G F of the parallelogram are equal, the angles H E F and I G F are equal; and because E H F and G I F are right angles, the triangles E H F and G I F are similar; therefore F G : F E : : F I : F H; but E D is equal to F G, and G D is equal to F E, therefore E D : G D : : F I : F H; that is, the force acting at A is to the force acting at C, as F I to F H.

Case II. *Figure* 11.—When the point F, is taken in one of the extreme lines of the direction, A D. On D F, as a diagonal, complete the parallelogram D E F G; draw F H perpendicular to D B, and F I to D C; then because G F H and E F I are right angles, and the angle I F H is common, the remaining angles I F G and H F E are equal; and because the angles F I G and F H E are right angles, the triangles G I F and E H F are similar; therefore F G : F E : : F I : F H; that is, the forces at B and C are reciprocally as the distances of their lines of direction taken from any point in the lines of direction of the other force. Therefore, universally, if any three forces be in equilibrio, any two of them are reciprocally as the distances of their lines of direction, taken from any point in the line of direction of the other force.

Proposition X. *Figures* 12 and 13.—If a solid, A B C, be supported by three forces in the lines of direction Z B, A W, C J, these three lines will have the same point of concourse, or be parallel to each other.

Join A B, B C, C A; now the triangle A B C cannot be in equilibrio, unless the directions have the same point of concourse, or be parallel, and also in the plane of the triangle; otherwise the forces at the two points in each of the sides of the triangle would not be equal in opposite directions; therefore the equilibrium of the triangle would be destroyed, as has been shown by Proposition VIII., and consequently that of the solid would also be destroyed.

Corollary 1.—The intensities of any three forces keeping a solid in epuilibrio, will be as the parts of a parallelogram formed on their lines of direction.

Corollary 2.—Likewise the intensities of any two forces are reciprocally as the distances of their lines of direction from any point in the line of the other force, whether their directions meet or are parallel to each other.

Corollary 3.—Hence, in three forces acting upon a prismatic solid, or lever, in parallel directions, any two forces will be to each other in the reciprocal ratio of the distances of their lines of direction, on the opposite side of the solid, to the direction of the other force.

Proposition XI.—If a solid be in equilibrio by three forces, and if any point be taken in the line of direction of any one of them: the products of each of the other two, by the distance of their respective lines of direction from that point, will be equal. *Figure* 14.

Let A, B, C, represent the intensities at A, B, C, in the directions E A, G B, F C. Take any point, D, in the middle line of direction, and draw D E, D F perpendicular to the other two lines of direction; then (*Corollary* 2, last Problem) A : C : : D F : D E; therefore A D E = C × D F. Again, from any point, F, in one of the extreme lines of direction, draw F G and F H perpendicular to the other two, then A : B : : F G : I H; therefore A × F H = B × F G.

Corollary 4.—Hence, if three forces act perpendicular to a prismatic rod, or beam, the products of any two, each by its distance on the beam from the third, are equal.

Corollary 5.—Hence, if three forces act perpendicular to a prismatic rod, or beam, the products of any two of their distances from the third, in the direction of the beam, are equal; for in this case all the lines, F D, D E, F G, F H, coincide in one straight line, and become parallel to the beam, and the segments intercepted by the directions are equal to those on the beam.

LEVER BOARDS, a set of boards so fastened together that they may be turned at any angle to admit of more or less air or light, or to lap upon each other, so as to exclude all air or light through apertures.

LIBRARY, an edifice or apartment destined for holding a considerable number of books placed regularly on shelves; or the books themselves lodged in it. Some authors refer the origin of libraries to the Hebrews; and observe, that the care those people took for the preservation of their sacred books, and the memory of what concerned the action of their ancestors, became an example to other nations, particularly to the Egyptians. Osimandyas, king of Egypt, is said to have taken the hint first; and, according to Diodorus, had a library built in his palace, with this inscription over the door, ΨΥΧΗΣ ΙΑΤΡΕΙΟΝ. Nor were the Ptolemys, who reigned in the same country, less curious and magnificent in their books.

The scripture also speaks of a library of the kings of Persia, Ezra v. 17. vi. 1., which some imagine to have consisted of the historians of that nation, and of memoirs of the affairs of state; but, in effect, it appears rather to have been a repository of laws, charters, and ordinances of the kings. The Hebrew text calls it the house of treasures, and afterwards the house of the rolls, where the treasures were laid up. We may, with more justice, call that a library, mentioned in the second of Esdras to have been built by Nehemiah, and in which were preserved the books of the prophets, and of David, and the letters of their kings.

The first who erected a library at Athens was the tyrant Pisistratus: and yet Strabo refers the honour of it to Aristotle. That of Pisistratus was transported by Xerxes into Persia, and was afterwards brought back by Seleucus Nicanor to Athens. Long after, it was plundered by Sylla, and re-established by Adrian. Plutarch says, that under Eumenes there was a library at Pergamus, containing 200,000 books. Tyrannion, a celebrated grammarian, contemporary with Pompey, had a library of 30,000 volumes. That of Ptolemy Philadelphus, according to A. Gallius, contained 700,000 rolls, which were burnt by Cæsar's soldiers.

Constantine, and his successors, erected a magnificent library at Constantinople; which in the eighth century contained 300,000 volumes, all burnt by order of Leo Isaurus; and among the rest, a copy of the Iliad and Odyssey, written in letters of gold, on the entrails of a serpent.

The most celebrated libraries of ancient Rome, were the Ulpian, and the Palatine. They also boast much of the libraries of Paulus Æmilius, who conquered Perseus; of Lucilius Lucullus, of Assinius Pollio, Atticus, Julius Severus, Domitius Serenus, Pamphilius Martyr, and the emperors Gordian and Trajan.

Anciently, every large church had its library; as appears by the writings of St. Jerome, Anastasius, and others. Pope Nicholas laid the first foundation of that of the Vatican, in 1450.

The Bodleian library at Oxford, built on the foundation of that of duke Humphrey, exceeds that of any university in Europe, and even those of all the sovereigns of Europe, except the emperor's and the royal library of France, which are each of them much older. It was first opened in 1602, and has since found a great number of benefactors; particularly Sir Robert Cotton, Sir H. Savil, Archbishop Laud, Sir Kenelm Digby, Mr. Allen, Dr. Pococke, Mr. Selden, and others. The Vatican, the Medicean, that of Bessarion at Venice, and those just mentioned, exceed the Bodleian in Greek manuscripts; which yet outdoes them all in Oriental manuscripts.

As to printed books, the Ambrosian at Milan, and that of Wolfenbuttle, are two of the most remarkable, and yet both inferior to the Bodleian. The principal public libraries in London, beside that of the Museum, are those of the College of Heralds, of the College of Physicians, and of Doctors' Commons, to which latter every bishop, at the time of his consecration, gives at least £20, sometimes £50, for the purchase of books; those of Gray's Inn, Lincoln's Inn, Inner Temple, and Middle Temple; that of Lambeth, founded by archbishop Bancroft, in 1610, for the use of succeeding archbishops of Canterbury, and increased by the benefactions of archbishops Abbot, Sheldon, and Tennison, and said to consist of at least 15,000 printed books, and 617 volumes in manuscript; that of Redcross-street, founded by Dr. Daniel Williams, a presbyterian divine, and since enriched by many private benefactions; that of the Royal Society, called the Arundelian, or Norfolk library, because the principal part of the collection formerly belonged to the family of Arundel, and was given to the society by Henry Howard, afterwards duke of Norfolk, in 1666, which library has been increased by the valuable collection of Francis Aston, Esq., in 1715, and is continually increasing by the numerous benefactions of the works of its learned members, and others: those of St. Paul's, and of Sion College; the Queen's library, erected by Queen Caroline in 1737; and the Surgeons' library, kept in their hall in Lincoln's Inn Fields. In order to give some idea of the construction of a library, it will be necessary to know the different sizes of paper, and for this purpose the following table will be found useful:

		Inches.
1.	Foolscap	13½ by 16½
2.	Crown	15 20
3.	Demy	17½ 22
4.	Medium	18 23
5.	Royal	19¼ 24
6.	Super-royal	19¼ 27
7.	Elephant	23 28
8.	Imperial	22 30
9.	Columbier	23½ 34
10.	Atlas	26½ 34½
11.	Double Elephant, or Grand Eagle	26½ 40

The dimensions of the shelves, and their distances from each other, will therefore be determined by the kind of books intended to be deposited on them.

LIBRARY, *the King's*, at St. James's, was founded by Henry, eldest son of James I. and made up partly of books, and partly of manuscripts, with many other curiosities, for the advancement of learning. It has received many additions from the libraries of Isaac Casaubon, and others.

LIBRARY, *Cottonian*, originally consisted of 958 volumes of original charters, grants, instruments, letters of sovereign

princes, transaction between this and other kingdoms and states, genealogies, histories, registers of monasteries, remains of Saxon laws, the book of Genesis, thought to be the most ancient Greek copy extant, said to have been written by Origen in the second century, and the curious Alexandrian copy or manuscript in Greek capitals. This library is kept in the British Museum, with the large valuable library of Sir Hans Sloane, amounting to upwards of 42,000 volumes, &c. There are many public libraries belonging to the several colleges at Oxford and Cambridge, and the universities of North Britain.

LIGHTHOUSE, a marine building, erected for the purpose of exhibiting a light, to warn seamen in the night of their approach to any sand, promontory, or insulated rock: as those on the South Foreland, Flamborough Head, the Eddystone, &c.; or a building erected at the entrance of a harbour, to direct the ingress and egress of vessels during the night, as at Ramsgate, and other places. The latter kind are generally smaller than the former, and are called *harbour-lights*.

Lighthouses are generally built in the form of circular towers, from 50 to 100 feet in height, arched over at the top with a projecting platform surrounded by an iron railing. On this platform a framing of stone is fixed higher than the railing, containing an excavation for the reception of the bottom of the lantern; the space between this frame and the railing, is called *the gallery*, into which the light-keepers ascend to clean the outside of the glass.

When lighthouses are erected on the main land, there is nothing peculiar in their construction; in some cases, however, they are required in situations difficult of access, and exposed to the accumulated fury of winds and waves; and to erect a permanent building on a spot of this description, requires uncommon resources, and necessarily brings every energy of the architect into action.

The most celebrated antique building of this description was the Pharos of Alexandria in Egypt, the work of Sostratus of Cnidus, under the patronage of Ptolemy Lagus, and his successor Philadelphus, about 283 years before the Christian æra; it is ascertained to have existed for a period of about 1,600 years, and is supposed to have been thrown down by an earthquake. This lighthouse obtained its name from the Island of Pharos, on which it stood; and from its great celebrity, other structures of a similar kind have frequently obtained the same name; as the *Faro di Messina*, and others; but among the moderns, the most remarkable are the *Tour de Corduan* off the French coast, and the *Eddystone Lighthouse*, near the coast of Cornwall. The former of these, begun in the reign of Henry II., and finished under Henry IV. in 1610, stands upon a small island near the mouth of the Garonne, in the Bay of Biscay, and was the work of Luis de Foix, a celebrated French architect. The latter, which has been very justly considered as the *chef-d'œuvre* of this species of architecture, was constructed by the celebrated Smeaton; and still stands an enduring monument of his genius. A full description of this remarkable structure has already been given under the article Eddystone Lighthouse.

Among other remarkable buildings of this kind may be noted the Bell-rock lighthouse, off Arbroath, in the mouth of the Frith of Tay.

The reef of rocks on which the Bell-rock lighthouse is founded, is about 427 feet long and 230 feet broad; at the ordinary height of spring tides it is about 12 feet under water; and from the floating sea-weed, the ridge can be traced 1,000 feet farther in a south-westerly direction, when the tides are very low. It is situated on the eastern coast of Scotland, about 16 miles south by east from the Red-head; 12 miles south-east from Arbroath; 17 miles north by east from the isle of May; and 38 miles north by west from Abbs-head. Its geographical position is in 56° 29′ of north latitude, and 2° 22′ of west longitude. The reef presents an exceedingly rugged and uneven surface. The rock is composed of red sand-stone, similar to the strata of the contiguous promontory of Red-head and of the opposite shores of Dunglas in Berwickshire. The present vegetation of the rock consists only of sea-plants; some of them not of common occurrence on our coast. It is the occasional resting-place of the seal and the cormorant; and is the chosen residence of numerous marine *vermes*. At the distance of 100 yards, when the tide is low, the water varies from two to three fathoms in depth. The greatest depth between the rock and the opposite shores of Fife is 23 fathoms. This rock, though a mere spot on the surface of the ocean, produces all the remarkable phenomena of in-shore and off-shore tides, which exist on the projecting coasts of the mainland, or among the Scottish islands.

In the erection of the Eddystone lighthouse, the dangers and difficulties which were encountered and overcome, owing to the smallness of the surface of the rock, were great and numerous; and although the surface of the Bell-rock was considerably larger, still, being more sunk, and only discovered at low water, the dangers to be encountered were equally great and overwhelming. Owing to the enlarged diameter of the rock, the engineer was enabled to make the masonry of this building more than double the cubical contents of the Eddystone. The following short table will exhibit to our readers the relative dimensions, &c. of the two lighthouses:—

	Eddystone.	Bell-rock.
Height of the rock, about	Level with high water mark.	Level with low water mark
Height of masonry above the rock ..	70 feet.	100 feet.
Diameter of the first entire course ..	26 feet.	42 feet.
Cubic contents in feet, about	13,147.	28,530
Expense understood to have been about	£21,000.	Ascertained. £61,331 9 2

Very early, no doubt, attempts were made to obviate the dangers of this fatal spot; and accordingly, tradition reports that the monks of the Abbey of Arbroath erected a bell on the rock, which was to be rung by machinery affected by the flowing and ebbing of the tides, whence the present name of the rock, it is said, took its rise.

After many complaints of the want of a lighthouse, and especially after the violent storm in 1799, during which many ships were driven from their moorings in Yarmouth Roads, and even the Downs, and so many of them destroyed on the Scotch coast, that, when the storm subsided all the bays were margined by broken timber, it was at last resolved to construct a lighthouse. A bill for this purpose was passed in 1806, which enabled the commissioners of the northern lighthouses to levy three-halfpence a ton upon all British vessels trading to and from the ports between Berwick and Peterhead, and twice as much upon foreign vessels. The bill also empowered the commissioners to borrow £25,000 from government; and they had £20,000 of accumulated surplus, which showed that the provision of lights had not previously been kept up to the amount of the tax upon navigation. Still, however, this enabled the commissioners to begin the work with a fund of £45,000. While the proposal was in agitation, various projects for lighthouses were advanced by different individuals; but it was ultimately resolved that the structure should be of stone, somewhat similar to the Eddystone lighthouse, and conducted under the principal superintendence of the late Mr. Rennie. It was well for the stability of the structure,

and the benefit of trade, that this eminent and judicious engineer was appointed, for there were other parties who occasionally interfered in the progress of the work; and some of the courses of stone intended for, and actually prepared in the workyard at Arbroath, were, for want of central dovetailing, so faulty, that, had they been used, the work could not have stood. These courses of stone were condemned by Mr. Rennie, and ordered to be broken up for rubble, as appeared by the signature of Mr. Rennie, on the plans. By the necessary condemnation of these faulty courses of stone, a considerable sum of money was lost, but the stability of the lighthouse was not endangered, which was the grand matter; and this shows how very careful eminent engineers, who are not constantly on the spot, ought to be, in examining every working drawing of such structures as this, and allowing no drawing to be used which is not authenticated by their signature. We do not now recollect all the faults of these condemned courses; and since the death of Mr. Logan, who was in possession of the plans with Mr. Rennie's signatures, we know not where these drawings can be referred to, (and reference to them is of little consequence, except as a warning;) but we do remember, that what struck us at the time as the grand imperfection, was the omission of the square central stone with dovetails, to which the four stones next in order were attached, and also joggled by stone to the end joints, thus making the five one mass of stone, to which the whole of the surrounding stones were attached. In place of this central stone, which was of course the key and fastening of the whole, there was substituted in the drawings, a plain hexagon or octagon, we forget which; by means whereof the whole bonding of the course was loosened, and, had water percolated into it, it would have been destroyed by the hydrostatical pressure. An accident of this kind happened to another structure which the engineer to the commissioners of the northern lighthouses had planned, and was in the course of erection upon the Carr rocks, off the east point of Fife. This structure was to be furnished with a bell, to be rung by a float; and in order to contain the float, a hollow column was erected, having a lateral opening at the bottom. The column was, we believe, pretty well secured against the external action of the water, but it should seem that the danger of hydrostatical pressure from within had been overlooked, for, after the work had advanced so far as to be distinctly visible from the land, the sea beating over it during a violent storm, had thrown in rubbish which blocked up the lower aperture, and the hollow of the column filled with water, which burst it into pieces, so that it vanished before it was finished. As this structure is gone, and has left no memorial, it would be of little consequence to inquire into any particulars of it; but the fact is worthy of record, as tending to show how very careful engineers should be in attending to every principle in the planning and executing marine structures; and also how careful those who direct the building of such structures ought to be in the selection of their engineers. To suffer, in any lighthouse or beacon-tower for the warning of mariners of the perils of the sea, any weak portion or point which shall endanger the stability of the structure, may be attended with more calamitous effects, at least for a time, than having no lighthouse or beacon at all; for the lighthouse or beacon gives the seaman a certain security, which prevents him from avoiding the danger so assiduously as he would do, were there no lighthouse there; and, therefore, he is tempted toward the rocks; and wrecked upon them, if the lighthouse falls before his arrival. The Bell-rock lighthouse is as secure against any casualty of this kind as a structure of human erection can be; and, from what we have stated, those who navigate the dangerous coast on which it stands cannot be too thankful to Rennie, who had the superintendence of the building, or hold the memory of that eminent and most judicious engineer in too high estimation.

While, however, this tribute is justly due, and ought to be paid, to the memory of Mr. Rennie, Mr. Logan, under whose care the work was more immediately executed, ought not to be forgotten. Perhaps no man was ever more capable of executing stone-work to bear the violence of the sea; and, let the plan be ever so good, a work may be rendered unstable by ignorant or negligent execution. Logan had been trained from his infancy in aquatic architecture, more especially in the construction of bridges which had to resist the action of violent floods; and, therefore, though a very young man when employed in the Bell-rock Lighthouse, he well knew the nature of the work, and was most faithful in the execution of it. His execution of the Dundee harbour, under Telford, and of the packet harbours between Ireland and Scotland, under Rennie, are lasting monuments of his ability; and had he not been prematurely cut off, there is no doubt that his operations on the Clyde would have been of the greatest benefit to Glasgow, and to all who are any way connected with it. Indeed, his professional zeal may be considered as the real cause which shortened his days; for when laying the foundations of the Dundee harbour, some of which was in very deep water, he was constantly on the ground when the tide permitted, and standing in the water for hours, directing and encouraging the men, whether it was night or day, and whatever was the state of the weather. This labour and exposure, which would very soon have killed most men, brought upon him a severe and long-protracted rheumatic fever; and, though the natural strength of his constitution enabled him to survive this for many years, he never thoroughly recovered from it.

In enumerating those who were chiefly instrumental in making the Bell-rock Lighthouse what it is, there is another and a different character, whom it would be injustice to pass over in silence: this was Watt, the machinist, or, more strictly speaking, the man of all work, or rather of all contrivance in cases of emergency. As is but too frequently the case with workmen of great inventive talent, Watt was somewhat dissipated, and passed not a little of his time in ale-houses. In this matter he was allowed to have his way, only to be always ready at a call; and when the course of the work rendered a crane, or crab, or other engine of peculiar construction, necessary, Watt was sent for, and instantly sketched out, rudely enough in some instances, the very machine which answered the purpose; and having done so, he returned to his potations. Among his contrivances we may mention two cranes, which are certainly superior to any other for laying heavy stone in difficult situations. One of those was a "jib-crane," of great power and easy management: it was supported by four gye-ropes in the usual manner, and traversed freely all round. The jib or arm was jointed to the pillar, so that it could be brought into all positions from horizontal to vertical; and, to prevent it from lapping to the pillar when raised, or beyond a certain elevation, the jib-chain by which it was raised or lowered passed over a pully in the bight, so as always to give a downward pressure on the point of the jib, where the pully of the crane chain was attached. It was worked by wheel and pinion, and, of course, required two sets of "geer"—one for working the jib, and the other for working the crane. By means of these contrivances, the largest stones—some of which were two tons in weight—could be brought to any point within the range of the jib, with great certainty, and very little manual labour.

While the building was solid, and of such moderate height as that the gye-ropes could be fastened, this crane answered

exceedingly well; but after the structure had advanced some height, and especially after it began to be hollow, a crane of this description could not be so fastened as to command the whole surface and have sufficient security. Consequently, the invention of Watt had to be called in; and he contrived his counterpoise crane. This crane was supported on a hollow pillar of cast-iron, which was lengthened by adding additional pieces as the progress of the work required. The crane, which was a platform with two equal arms, traversed upon this pillar, and was of sufficient length to command the whole work, and as much more as sufficed for raising the stones. To the one arm was attached the chain for this purpose, while the other carried a hook, upon which weights could be placed, to counterbalance that of the stone; and the working parts were so arranged, that when the stone required to be moved outwards or inwards to bring it to its proper bed, the weights were also moved outwards or inwards, and thus the leverage of both ends of the crane was always equal, as well as the weight. Thus it traversed freely, was easily worked, and perfectly stable. One of the barrels also raised the platform of the crane by means of a pulley and chain on the top of the pillar; and there were apertures through both sides of the pillar, for supporting the platform when raised to the proper height. When the pillar itself required to be lengthened, the pulley was removed from the top of the pillar, a new piece of pillar added, the pulley replaced, and the chain lengthened and passed over it as before. In this way, by adding length after length, the laying of the stones by means of the counterpoise crane was carried on to the required height with ease, expedition, and safety, which could not have been maintained without such an apparatus.

The lighthouse itself is a splendid structure, of which the external contour is good, and also the execution. The height of the masonry is 100 feet, and the light-room or lantern is 15 feet more. The diameter at the base is 42 feet; but at the parapet of the lantern, is only 13 feet. The first 30 feet consist of solid masonry, the lower courses let in, and treenailed to the rock, and all the solid courses are dovetailed, joggled, and treenailed; and as they are laid in strong mortar, which sets readily and firmly, the whole of this 30 feet has very nearly the cohesion of one solid mass of stone.

The entrance and lowest apartment is at the top of this solid masonry, and there is an external stair and platform for landing when the tide suits. The walls of this apartment are 7 feet thick; it is occupied by the water-tanks, fuel, and other heavy necessaries. The second, which is much more ample, in consequence of the reduced thickness of the walls, contains the oil and other stores necessary for the lights. The third floor is the kitchen, and the fourth the bedroom for the keepers; and the fifth room is the library, and place for the reception of such strangers as have hardihood to visit this sea-girt pillar. Over all these is the light-room, with double glazed windows, and wholly fire-proof, except the external dead-lights, which are put on as occasion requires. The balcony around the light-room is well secured by a cast-iron railing, supported with brass, and having a strong top-rail of that metal. The parapet of the light-room is six feet high, and from it a door opens to the balcony. The sashes of the windows are of cast-iron, the glazing strong plate double, as we have said, and the dome is of copper. The lights are revolving ones, and show alternately a white and red light, produced by stained glass. They are very powerful, and can readily be seen at a distance of 20 miles or more, unless when the atmosphere is foggy; and unfortunately, no light has yet been discovered which can so far penetrate a thick fog as to warn a ship of danger in time for even a chance of escaping.

As the best substitute that circumstances admit of, two bells of 12 cwt. each are tolled constantly day and night, when the atmosphere is foggy, by means of the same machinery which moves the lights. In calm weather, during which fogs are most frequent, the sound of these bells can be heard all over the surface of the rock which is absolutely dangerous; and thus they justify the appellation of Bell-rock lighthouse, and remind one of the Abbot of St. Thomas.

The rise of the tide over the foundations of the lighthouse is about 16 feet at ordinary spring floods; and when the sea is perfectly tranquil, the structure seems resting on the waters. Altogether, indeed, the Bell-rock lighthouse is a structure of great interest, and one which has been the means of saving many lives and much property. Considering that the workmen had to contend with the violence of the sea, upon a rock 12 miles from land, and with its highest point 12 feet below the surface of high water; it will be readily understood that the commencement of the work, and all the early stages of it, must have been attended with great difficulty and no small danger. A faithful history of its construction, drawn up with even the tithe of the talent which Smeaton displays in his report on Eddystone, would be an interesting and instructive work; unfortunately, there was no Smeaton conversant with all the details of the Bell-rock; and the result is, that all the published accounts of it are meagre, and some of them perhaps not true.

Another noble erection of this kind is that on the Skerry-more rock, off the west coast of Scotland. This building was constructed from the designs of Mr. Alvan Stevenson, the talented engineer to the Scottish Lighthouse Board, and cost in its erection, with the harbour for the tender and other necessaries, £87,000; it was first illuminated in 1844. The light is 150 feet above the sea, and the structure and its appliances exhibit every refinement and improvement hitherto effected by modern science in the varied particulars of the system.

Although, however, the talent and practical ability of such men as Smeaton and Rennie enabled them to overcome all the difficulties of constructing such buildings as we have described, other situations, where also it was desirable to erect them, presented obstacles of another character, perhaps even still more troublesome to deal with; we allude to the erecting lighthouses on such shifting and dangerous sands as the Goodwin, &c. Here the engineer has no solid rock to build on; instead of a substantial foundation on which to base his work, he has to work on a treacherous material, which slides from under him, and engulfs all that is placed on it.

Of the means for meeting such difficulties, the first to be noticed is the *screw-pile* of Mr. Alexander Mitchell, C. E. of Belfast. This principle was first employed in the construction of the foundation of the Maplin Lighthouse, on the north side of the mouth of the Thames, on which is now exhibited a red light. This was commenced in 1838, and is as firm now as when first erected; it stands on the outer edge of the Maplin Sand. This dangerous shoal is composed of sand at the surface, and afterwards of sand and mud; it is exceedingly soft and penetrable, and therefore the erection of a lighthouse upon such a foundation must be considered as a great achievement.

The principle of this screw-pile lighthouse, is having a series of piles nine in number—eight in the angles of an octagon, and one in the centre. These piles consist of a shaft of hammered iron, five or six inches in diameter, having a single turn of the flange of a screw four feet in diameter. This pile is screwed with great facility into the sand, to the depth of 22 feet; and each, it was calculated, would bear a weight of 64 tons. Nine piles were fixed in nine consecutive days in the summer of 1838, and upon this foundation

of Mr. Mitchell's, the light-room was erected under the direction of Mr. Walker, the engineer to the Trinity Board.

A structure similar to this was proposed by Mr. Robert Stevenson in 1800, for the Bell-rock lighthouse. It was intended to affix the foundation to the rocks, and that the iron shafts should support several stories; whereas the Maplin and Wyre lights have but a single story. A similar structure is also now building on the rocks of Minot's Ledge off Boston, in the United States; and another is constructing in London for the Bishop Rock off Scilly, designed by Mr. Walker. Mr. Mitchell previously completed a lighthouse upon a similar foundation at the mouth of the Wyre river, in Morecambe bay, about 30 miles north of Liverpool. It was commenced in November, 1839, and lighted in June, 1840. The foundation is formed of seven screw-piles, six in a circle, and one in the centre, each pile being five inches in diameter, with a screw of three feet diameter. The screws were sunk 13 feet into the bank, which is composed of exceedingly hard sand. On these screws is supported the lighthouse, consisting of one floor only, and the lantern above it.

Another plan has been carried into effect, at the Point of Air lighthouse, at the entrance of the river Dee, near Chester. This, which is similar in superstructure to the Maplin lighthouse, is by Messrs. Walker and Burgess, and consists of nine hollow iron cylinders, 3 feet 9 inches in diameter, sunk 12 feet into the sand by aid of an instrument known to well-sinkers as "the Miser," which extracts the sand contained in the cylinder. In these the bases of the piles are inserted, and then filled with concrete. But this, it must be observed, is erected above low water-mark.

While on this point of the subject we may notice an admirable plan for forming a foundation for a bridge or pier of similar structure described by Mr. Charles Fox, of the firm of Fox, Henderson, and Company, in his evidence before the Committee on the Westminster Temporary Bridge bill in 1850.

This plan has been adopted with great success in the several bridges on different lines of railway, built by Messrs. Fox and Company, under the direction of Mr. Cubitt and other engineers; and though not yet, as we believe, applied to the building of lighthouses, seems well adapted to that purpose.

We cannot better describe this plan than in Mr. Fox's own words, in the following extract from the printed evidence of the Committee above mentioned.

"Will you describe to the Committee the mode of construction?—Perhaps the simplest mode of describing it is to say, that instead of using the old-fashioned wooden coffer-dam, which was always a temporary work, we make use of cylinders of iron, which are in themselves coffer-dams, and which remain permanently as a portion of the structure. We adopt various modes of getting them down, but the more general one is this: we have a large receiver of wrought-iron, very much like a cylindrical high-pressure boiler, and from that receiver we exhaust the atmosphere, and when we get the cylinder put into its place, just carefully lowered down on to the bed of the river, surrounded by temporary frames of timber, so as to be sure that it shall be kept in a vertical position, we put a cap on to the top, having an elastic pipe from the top cap to the exhausted receiver, and we, at the proper time, open the communication between the two, and the pressure of the atmosphere on the surface of the water in the river produces such a rush to fill up the tube, as to get rid of any vacuous space, that it carries on a constant state of excavation under the bottom edge of the cylinder, from the pressure of the atmosphere on the top. The atmosphere takes care to push down the pile, aided by its own weight, so as to take up any little space that may have been excavated. When this mode was first spoken of, it was treated with a great deal of ridicule, and people naturally said, 'Why, if the pressure of the atmosphere will push the pile down, when the pile is down it will not carry more than a weight equivalent to the pressure of the atmosphere;' and a very practical man raised that objection; not a very scientific man, but a man of very great experience; and I said to him, 'Now you are quite wrong, for the principle is, that it acts as a sort of excavating process; it is quite true that the pressure of the atmosphere on the top is useful, as it gets over any little friction on the sides of the tube so as to enable it to follow into the excavated space, and without that principle we could not push the cylinder down at all.' To prove this, we took a six-feet cylinder, and calculated what the pressure of the atmosphere upon that cylinder would be, and taking the whole pressure of the atmosphere, it amounted to about 30 tons. I had 30 tons of iron rails placed on the top of the cylinder, and the only result was, that it pushed it down about three-quarters of an inch into the gravel and brought it to a bearing, but it did no more.

"Was that upon a cylinder of six feet in diameter?—Yes; we then took off the 30 tons of iron-rails and put on the cap and opened the communication with the exhausted receiver, and the cylinder immediately descended into the solid gravel 6 feet 6 inches by one impulse.

"Having descended only three-quarters of an inch before?—Only three-quarters of an inch; it just pressed it a little into the ground with the dead pressure of 30 tons. We then removed the cap, and put on the top of the pile 100 tons of rails; but we could get no depression, except some three-quarters of an inch, which was done by the little compression that you would have from the weight of the edge of the cylinder on the gravel. That is the general mode of sinking these cast-iron cylinders. But as it will be obvious to the Committee, in the event of our meeting with, say, the trunk of an old tree, or a very large stone, we could not proceed any further, and we have had to devise many means of getting over any difficulty of that kind. In the case of the bridge at the Nene, we have had to go through not only a layer or two of gravel, but through 2 feet 6 inches of solid rock, and that rock not lying in a horizontal position, has offered difficulties which, under other circumstances, would be very expensive to overcome. To enable us to get through any unforeseen matter, it is necessary to get into the cylinder and excavate any material that may be within it, and cut through the obstruction; and, to do that, we have devised a means by which we convert the cylinder virtually into a diving-bell; that is to say, we fix a cap on the top of the cylinder, and the air-pumps are constructed so that they are, when required, compressing-pumps, and we can pump just enough air into the cylinder to make it counterbalance the pressure of the column of water without, by which means we keep the work perfectly dry, and the men can get at it just as well as if they were working in this room.

"What is the greatest depth to which you have driven a single cylinder?—I think the greatest depth to which we have driven a single cylinder is about 19 feet; but one has been driven in the Goodwin Sands 65 feet by the same process.

"The Committee understand that the cylinders are not single, but are piled one upon each other to the required depth?—Exactly so; they are generally used in nine-feet lengths; the piles for the bridge at Rochester are of two diameters, they are six feet and seven feet, and they are cast

in lengths of nine feet, with flanges at the top and bottom, which are accurately turned and fitted together, so that they drop on to one another; there is a projection.

"The external water will be found to be effectually excluded by such a mode of junction?—Perfectly; we never have a drop through them; they require nothing more than a single coat of paint, and when we use one of the castings we clean the flange carefully and give it one coat of good red lead paint, and put another down upon it, which is prepared in the same way; they never leak a drop.

"Do you recommend as a general principle the adoption of a cylinder or of a square form?—Generally a cylinder, for several reasons.

"Will you state the reasons?—In the first place, because it is the cheapest form to construct in the preparation of the casting itself; and, in the second place, because it is better capable of bearing pressure, and therefore can be cast with a much less quantity of material in it; the object in a foundation being to get the largest bearing surface at the least possible cost; in the third place, because we have found in practice that it is difficult to sink square caissons close together, because, having a very small space between them, one having been sunk, it is very apt to make it difficult to sink an adjoining one; we have no ground between them to work upon.

"The Committee understand, likewise, that there is round each cylinder a girdle of timber, which is necessary in order to keep the cylinder in its perpendicular position?—Yes; I have made use of piles upon which temporary frames are fixed, and put two rows of what we call wallings, forming a square space, in which the cylindrical pile is placed and driven by means of the pressure on the cap of the cylinder.

"Are the Committee to understand that the surface, or the bed of the river, is in the first instance level, in order to receive the cylinder?—Not at all; we deal with it as we find it.

"You use no mechanical means, except in the experiment to which you have adverted, of 30 tons and 100 tons of actual weight; you have recourse rather to physical means of exhausting the air, and of admitting the pressure of the atmosphere?—Yes, because it is so much cheaper. It is a serious job to put 30 tons on to a pile, whereas a simple cast-iron cap, as I have before described, put on to the top is so exceedingly easy."

In another part of his evidence, Mr. Fox says, "There is no doubt that the cheapest foundation you can put in is to use the largest size cylinders, so as to have them within the compass of ordinary means of moving about. If you had a pile two feet in diameter it would bear a certain load, supposing it to be in any semifluid foundation; if you double the diameter, you would only double the weight of the cylinder, but it would carry four times the load." Again, —and this is peculiarly applicable to foundations on sands, &c., for lighthouses—"If you give me a piece of ground, and first there is a layer of mud, and then a layer of gravel, and then a layer of rock, and then a sheet of cast-iron, and then anything else, I will put a cylinder through it. I also will bring up the foundations of the bridge to low-water level, for something like the same cost as would have been expended under the old plan, in the mere material used for that purpose, saving coffer-dams altogether."

Mr. Bush's "Light of all nations," though it failed so signally, deserved notice. This was again a proposal to construct a lighthouse on the Goodwin, ever a locality for experiments of this nature. The site at last chosen was, for any good effect to be derived from it, as bad as could possibly be. being on the middle of the sand, and consequently calculated rather to lead vessels into danger, than to preserve them from it.

"The Light of all nations" was intended to be an iron tower erected by means of an iron caisson, which was to afford the means of forming a substantial foundation. This caisson, the frustum of a cone 30 feet in diameter, and 28 feet high, weighing about 150 tons, was towed out from Deal by one of Her Majesty's vessels to its station, about the centre of the Goodwin Sands, on July 27, 1842. The caisson was made water-tight, in order that, as it settled down, the workmen might be enabled to construct the foundation on the chalk substratum of the sand. This substratum, however, was never reached; the caisson did settle down, but not perpendicularly, and after it had been knocked about by several gales of wind, it was found impracticable to carry out the original design, and it was therefore necessarily abandoned. On the wreck of the caisson, however, Mr. Bush succeeded in erecting a smaller shaft, surmounted by a small light-room, and in this room he and his wife remained during a night in the beginning of 1845.

The lighthouse was never completed. And the Trinity House was at last obliged to interfere, to prevent, from its dangerous situation, its being used as a light-beacon.

Another adaptation of iron to the construction of lighthouses has met with far greater success, and promises to be of the greatest utility, whether as regards economy, or facility of construction. This is the iron lighthouse designed by Mr. Gordon.

It is rather singular that iron should not have been employed in this form before, when we consider the multifarious variety of purposes to which it is now applied. In the year 1805, however, a cast-iron lighthouse was suggested by Mr. Rennie, for the Bell-rock, and also by Mr. Robert Stevenson in 1800. The first tower of this construction, was erected on the eastern end of the island of Jamaica, and another of a similar kind for Bermuda. The latter is 105 feet 9 inches high, formed with iron plates, the entire weight of which is nearly 100 tons. The building has seven stories, and the lower portion is filled in with concrete to the height of 22 feet, to give it stability. Nearly every portion of the edifice is of iron, and the erection of the tower was completed in ten months, finished October 9, 1845. These lighthouses were constructed in London, put together and erected, and then taken to pieces again and forwarded to their destination.

The light in the Bermuda lighthouse is from a beautiful dioptric first order apparatus, constructed by Messrs. Wilkins and Son, of Long Acre; the lenses composing it were made by M. H. Lepante of Paris, and is one of the most efficient and powerful lights in the world.

Having thus shown some of the different methods employed in the erection of lighthouses, and the improvements which modern art has introduced, we now turn to another important part of our subject, that of the *illumination* of lighthouses.

The first lighthouses, such as the Cordouan, and the North Foreland, were illuminated by open fire-places, or chauffers, placed on the summit of the towers. In the former, they burnt billets of oak-wood; and in the latter, coal. It will be readily seen how incompletely such arrangements must have performed their office. Of course the time at which a lighthouse becomes most serviceable is, during tempestuous weather, and a wind blowing towards the land, causes that dread of mariners—a lee-shore; yet this wind would drive the flames of an open fire away from the very direction in which they were most required to be seen; thus the bars of the grate were often nearly melted to leeward, while towards the sea the coals remained untouched by the fire. One advantage, however, there certainly was sometimes in the open fire, viz., that

during fog or rain, the glare of the fire was visible by reflection in the atmosphere, though the fire itself could not be seen.

The North Foreland lighthouse, between Ramsgate and Margate will be more familiar to many of our readers than any other, and will serve as an excellent example of the progress of illumination. This lighthouse was erected for indicating the proximity of the Goodwin Sands. The first intimation we have of its existence is in 1636, in Charles the First's reign, when license was granted to Sir John Meldrum to renew and continue this and the South Foreland lighthouse for the same purpose. At this time it was merely a large glass lantern on the top of a timber-and-plaister house, which was burnt in 1683. Towards the end of the same century, the present tower was partially erected; a strong octagonal structure, having the iron grate, or chauffer, for burning coals. From the difficulty of keeping up a proper flame in windy or rainy weather, it was covered about the year 1732, with a sort of lantern, with large sash windows, and the coal fire was kept alight by means of large bellows which the attendants blew throughout the night. This was found not to answer, and the reflected glare above-mentioned was thought desirable. Accordingly, the lantern was removed, and the fire restored to its original condition. Matters went on thus till 1790, when the tower was raised to the height of 70 feet, and further improvements made in the lantern, by the introduction of lamps and other apparatus, hereafter to be described.

After some alterations of the Cordouan wood-fire, the mariners complained that they could not see the light at a distance of two leagues, as formerly. But Smeaton informs us, that the coal-fire of the Spurn Point lighthouse, at the mouth of the Humber, which was constructed on a good principle for burning, had been seen thirty miles off.

The only exceptions to the fires were the noble Eddystone lights, which then exhibited a chandelier of twenty-four wax candles, five of which weighed 2lbs., and the Liverpool lighthouses, which had oil lamps, with rude reflectors.

The coal lights are now quite abolished. The last was at one station belonging to Sweden, on the little island of Nidingen, on the east side of the Categat, near the entrance to the Baltic sea. These were two light towers, showing coal fires, but surrounded by sides of glass, to shelter them from the wind, and open at the top. They were altered at the beginning of the year 1846.

The introduction of the Argand lamp was the first great advance towards the perfection of lighthouses. This improvement in artificial light was the greatest, previous to the introduction of gas. It was discovered by M. Argand, a citizen of Geneva, about 1780 or 1785. It has remained as he left it, and in principle appears as perfect as can be looked for. Its perfection as an experiment was almost accidental. The younger brother of Argand thus describes its accidental discovery. "My brother," he says, "had long been trying to bring his lamp to bear. A broken-off neck of a flask was lying on the chimney-piece; I happened to reach it over the table, and to place it over the circular flame of the lamp; immediately it rose with brilliancy. My brother started from his seat in exstasy, rushed upon me with a transport of joy, and embraced me with rapture." Thus originated the Argand lamp.

On the introduction of a more efficient means of illumination, and the consequent abandonment of the coal fires, lighthouses assumed a more important position in maritime affairs, and they were, accordingly, largely increased in number. This extension rendered necessary another improvement—the means of readily distinguishing one light from another. Although many suggestions have been made for doing this more effectually—some practicable, others not so, and some are in actual operation—this part of the science is far from being in a perfect state. Much remains to be done, before the mariner can be certain of determining, by its distinctive features, each light when seen.

The variety of lights that have been proposed and experimented on for lighthouse purposes is very great, particularly, we may mention, the Drummond, the electric, voltaic, &c., but few have stood the test of experience; and the lamps now in universal use are still but modifications of the original Argand burner.

Amongst the means for increasing the intensity of light, the use of reflectors is most important. In the year 1786, reflectors and oil lamps were first proposed at a meeting of the Scottish lighthouse commissioners. The first metallic reflectors used in the northern lighthouses were constructed by Mr. Thomas Smith, of Edinburgh. The figure was given to them by a plaster mould, and the cavity was afterwards filled in, by means of cement, with small facets of mirror-glass. This must have done its work very imperfectly, although the general figure was capable of considerable accuracy. In 1803, the first polished *metal* reflectors used in Scotland, were placed in Inch-Keith lighthouse; since then, various slight alterations and improvements have been made, but substantially, the system of illuminating lighthouses remains the same.

We cannot conclude this article without acknowledging our obligations in its preparation to the valuable paper on lighthouses, &c., by Mr. Findlay.

LIKE ARCS, in the projection of the sphere, the parts of lesser circles containing an equal number of degrees with the corresponding arcs of greater circles.

LIKE FIGURES, in geometry, such as have their angles equal, and the sides about the equal angles proportional.

LIKE SOLIDS, such as are contained under like planes.

LIMESTONE, a calcareous stone, which being sufficiently burned or calcined, falls into powder on the application of water; and being then mixed with water and sand in certain proportions, forms a strong cement.

Limestone is either pure or mixed. The best for the use of building is that which contains a certain portion of clay and iron. *See* CEMENT.

LIME-KILN, a kiln for the purpose of burning lime. Kilns for this purpose are constructed in a variety of ways, to save expense, or to answer to the particular nature of the fuel. *See* KILN.

LIME, *quick*, a term applied to lime in its most powerful or caustic state, before it has been rendered mild by the absorption of carbonic acid gas, or fixed air. *See* CEMENT-KILN.

LINE, (from the Latin, *linea*,) a quantity extended in length only. A line may be conceived to be formed by the motion of a point. Lines have no real existence except at the termination or terminations of the surface of a body: thus, a line is the junction of two surfaces, and therefore can have no thickness.

Lines are of two kinds, viz., *straight* or *curved*. Straight lines are all of the same species; the species of curves, which are infinite, are divided into *geometrical* and *mechanical*.

LINE, also denotes a French measure, containing the 12th part of an inch, or the 144th part of a foot.

LINE, *Equinoctial*, the common intersection of the equinoctial and the dial planes.

LINE, *Geometrical*, in perspective, any straight line in the geometrical or primary line.

Line, *Horary*, or Hour Lines, in dialing, the intersection of the hour-planes with the dial plane.

Line, *Horizontal*, a line parallel to the horizon. In perspective, it is the vanishing line of horizontal planes.

Line, *Vertical*, the intersection of a vertical plane with the picture, passing along the station-line.

Line, *Visual*, a ray of light reflected from the object to the eye.

Line of Direction, in mechanics, the line in which motion is communicated.

Line of Light, in light and shade, a line on the curved surface of a body, such that any point taken in it will be lighter than an adjacent point taken out of it indefinitely near.

Line of Measures, a term used by Oughtred to denote the line on the primitive circle, in which the diameter of any circle to be projected falls.

In the stereographic projection of the sphere, the line of measures is that in which the plane of a great circle perpendicular to the plane of projections, and the oblique circle which is to be projected, intersect the plane of projection; or, it is the common section of a plane passing through the eye and the centre of the primitive at right angles to any oblique circle to be projected, in which the centre and pole of such circle are to be found.

Line of Shade, in light and shade, a line on the curved surface of a body, formed by a tangent surface of rays from the luminary to that of the body.

Line of Station, the intersection of a plane passing through the eye perpendicular to the picture and to the geometrical or primary plane, with the primary plane itself.

Lines, *Division*, or *Gradation of*, the various proportions into which lines may be divided; as arithmetical proportion, geometrical proportion, the squares of the distances from the beginning, and harmonical proportion.

Lines of the Proportional Compasses, are those of lines, of circles, of polygons, of planes, and of solids.

Lines on the Plain Scale, are the following, viz., of chords, of sines, of tangents, of secants, of semi-tangents, and of equal parts.

Lines of the Sector, are the following, viz., of equal parts, of lines, of chords, of sines, of tangents, of secants, of polygons, of numbers, of hours, of latitudes, of meridians, of planes, and of solids.

LINEAR PERSPECTIVE, the title given by Brook Taylor to his two celebrated essays on perspective.

LINING, the covering of the interior surface of a hollow body. When the exterior surface is covered with any thin substance, the body is said to be *cased*.

Lining, in canal making, the thickness or coat of puddle sometimes applied to the bottoms and sides of canals, to prevent them from leaking.

Lining of a Wall, a timber boarding, the edges of which are either rebated or grooved and tongued. Shops are generally lined; as are likewise water-closets, to the height of five or six feet.

Lining-out Stuff, the drawing of lines on a piece of timber, board, or plank, so as to cut it into boards, planks, scantlings, or laths.

Linings of Boxings, for window-shutters, the wooden boards or wainscoted framings which form the backs of the recesses into which the shutters are depressed. In good work, the linings are not only grooved and tongued into the inside lining of the sash-frame, but also into the framed ground around the margin of the window, and inner surface of the wall.

Linings of a Door, the internal facings of joinery surrounding the aperture of a door, placed in the thickness, and at right angles to the face of the wall, through which the aperture is made. The linings which cover the sides of the door are called *jambs*, or *jamb-linings*, and that which covers the head is called the *soffit*.

Lining of a Sash Frame, the vertical pieces of wood, parallel to the surface of the wall. In good work, the linings are always grooved to receive the tongues in the pulley-piece.

LINTEL, (from the French, *linteau*,) a beam of timber over an aperture, for sustaining the superincumbent part above, and the soffit, whether of wood or plaster, underneath.

The number of timbers required to lintel an aperture depends on the thickness of the wall: their depth, or altitudinal dimension, consists, in general, of as many inches as there are feet in the horizontal dimension of the aperture under them. If the wall be solid, without apertures above, the depth should be still greater. Lintels should be laid close to each other.

Lintels, are also a species of wall-timbers, and which, with bond-timbers and wall-plates, are all called by the general name of Fir-in-Bond.

Lintels, in some old books on carpentry, are also called *wall-plates;* but the word is not now used in this sense unless the joisting or tie-beams rest upon it; and then it is both a lintel and a wall-plate.

LIST, (from the Saxon, *lystan*,) or Listelo, (Italian.) *See* Fillet.

LISTING, in carpentry and joinery, the act of cutting away the sap-wood from one or both edges of a board.

LOBBY, (from the German *laube*,) a small hall or waiting-room, or the entrance into a principal apartment, where there is a considerable space between it and a portico or vestibule, but the length or dimensions will not allow it to be considered as a vestibule or ante-room.

LOCK, (from the Saxon, *loc*) a well-known instrument used for fastening doors, chests, &c., generally opened by a key. The lock is reckoned the master-piece in smithery; a great deal of art and delicacy being required in contriving and varying the wards, springs, bolts, &c., and adjusting them to the places where they are to be used, and to the several occasions of using them. From the various structure of locks, accommodated to their different intentions, they acquire various names. Those placed on outer doors are called *stock-locks;* those on chamber-doors, *spring-locks;* those on trunks, *trunk-locks*, *padlocks*, &c. Of these the spring-lock is most considerable, both for its frequency and the curiosity of its structure. Its principal parts are the main-plate, the cover-plate, and the pin-hole: to the main-plate belong the key-hole, top-hook, cross-wards, bolt-toe, or bolt-knab, drawback-spring tumbler, pin of the tumbler, and the staples; to the cover-plate belong the pin, main-ward, cross-ward, step-ward, or dap-ward; to the pin-hole belong the hook-ward, main cross-ward, shank, the pot or bread-bow-ward and bit.

The principle on which all locks depend is the application of a lever to an interior bolt, by means of a communication from without; so that by means of the latter, the lever acts upon the bolt, and in such a manner as to secure the lid or door from being opened by any pull or push from without. The security of locks in general therefore depends on the number of impediments we can interpose betwixt the lever (the key) and the bolt which secures the door; and these impediments are well known by the name of *wards*, the number and intricacy of which alone are supposed to distin-

guish a good lock from a bad one. If these wards, however, in an effectual manner, preclude the access of all other instruments beside the proper key, it is still possible for a mechanic of equal skill with the lockmaker, to open it without the key, and thus to elude the labour of the other. The excellence of locks consists in the security they afford; and as numberless schemes are continually brought forward by designing men, to elude every contrivance of the most ingenious mechanics, the invention of a durable lock, so constructed as to render it impossible for any person to open it without its proper key, has ever been an object of considerable importance.

Lock, or Weir, in inland navigation, all those works of wood or stone, or of both combined, for the purpose of confining and raising the water of a river.

The term *lock*, or *pound-lock*, more particularly denotes a contrivance, consisting of two gates, or two pairs of gates, called the *lock-gates*, and a chamber between them, in which the surface of the water may be made to coincide with that of the upper or lower canal, according as the upper or lower gates are opened; by which means boats are raised or lowered from one level to another.

Lock Paddles, the small sluices used in filling and emptying locks.

Lock Sills, the angular pieces of timber at the bottom of the lock, against which the gates shut.

Lock Weirs, or Paddle Weirs, the over-falls behind the upper gates, by which the waste water of the upper pond is let down through the paddle-holes into the chamber of the lock.

LOCKER, a small cupboard.

LOCUS (Latin), in geometry, the line described by the intersection of two lines in motion.

LOFT, a raised gallery, or room in roof.

LOG HOUSES, the huts constructed by the Americans of the trunks of trees.

LOGARITHMS, are series of artificial numbers, so arranged with reference to a set of natural numbers, that the addition of the logarithms shall correspond with the multiplication of the natural numbers belonging to them; and subtraction of logarithms answers for division; while involution, or the raising of powers, is performed by the multiplication of logarithms; and evolution, or the extraction of roots, by the division of logarithms.

LOGEUM, that part of the theatre where were placed the chorus, and others who were not to take an active part in the performance.

LOGGIA, a gallery or avenue, with open colonnade or arcade, on one or both sides.

LOGISTIC SPIRAL, or Proportional Spiral, one whose radii are in continued proportion where the radii are at equal angles; or it may be defined, a spiral whose radii everywhere makes equal angles with the tangents.

LOMBARDIC ARCHITECTURE, a style of architecture prevalent in Italy from the commencement of the seventh to the thirteenth century; it succeeded the debased Roman, and forms the intermediate link between it and the Gothic. It derives its name from the circumstance of its prevalence during the supremacy of the Lombards in Italy, and not from any notion of its invention or introduction by that people, for they had no architecture of their own, as is evident from the fact of their being compelled to employ native artists in the construction of their works. The style is indeed nothing more than a natural and gradual development of Roman architecture; and the principles involved in it had already begun to manifest themselves ere the fall of the empire. This mode of building, as well as those which preceded and followed it, owe their existence to the invention and adaptation of the arch to constructive purposes; and as the latest exhibits this new principle perfected and fully developed, so does the second manifest an improvement to and more perfect development than the earliest.

The Lombards, during whose dynasty this style prevailed, established themselves in Italy at the close of the sixth century, and remained in undisturbed possession of the country for two hundred years, when it was wrested from them by Charlemagne, who in 774 put an end to that dynasty, and united Italy to the new western empire. Italy does not seem to have suffered much, but rather the reverse, from their government, and during their possession, the arts flourished and were cultivated with greater success than during the periods either immediately preceding or following. It is certain that they gave a great impetus to building, for during the two hundred years of their sway, the northern and central portions of Italy had become studded with churches and baptisteries, amongst which we may give as examples, San Michele, Pavia; San Thomaso in limine, near Bergamo, and the baptistery at Florence. The influence of the style does not seem, however, to have been much felt at Rome, for during all this period, we know of only one Lombardic building in that city, the church of San Giovanni é Paolo.

The change of dynasty in A. D. 774, does not appear to have had any very great effect upon the arts, during the existence of the Carlovingian line, but when that line became extinct, A. D. 875, the troubles caused by the disputed claims of rival princes in the north, and by the incursions of the Saracens in the south, greatly impeded the progress of architecture. Matters were not greatly improved by the government of the German emperors, for at this time Italy was distracted with discord and civil commotions. The Carlovingian dynasty ceased, A. D. 875, and the German emperors acquired sovereignty in Italy about the middle of the tenth century, during all which time, and for half a century longer, architecture made but little or no progress. When the arts again flourished in the eleventh century, some little alterations had been introduced into the style of architecture, which were again increased and multiplied in the twelfth. Many churches were built in the Lombardic style during these two centuries, but in the next the Pointed style began to make appearance, and partially superseded its predecessor; we say partially, for the Pointed style never took very deep root in Italy, nor were the features of the Round style ever entirely effaced.

The Lombardic style may be classed under the general title of Romanesque, which comprises the debased Roman and all those styles which emanated from it, until we come to the Pointed or Gothic, including the Byzantine and Lombardic, as also the Norman and Saxon, which are essentially Lombardic in character, and may be considered as forming a subdivision of that style. The last two, however, will not be considered in the present article, but will be treated of separately.

The style under consideration, was employed almost exclusively in ecclesiastical structures; to them therefore we must look for its characteristic peculiarities. It was the adaptation of the arch to purposes of construction, as we have before stated, which gave rise to the grand revolution in classical architecture; it was the various modifications of the same feature which gave origin to the subdivisions of the new system. Of these, the Lombardic is characterized by the constant use of the semicircular arch for the purposes of construction and decoration, and more especially by the excessive employment for the latter purpose in the exteriors of buildings. The external walls were frequently almost

covered by a series of arcades rising in stories one above the other, on one or more sides, and sometimes all round the building. These were either blank arcades, that is, attached to the surface of the wall, and employed solely for ornament, or else they were detached and stood out from the wall, forming a sort of gallery or portico; they were more frequent in the façades of buildings than elsewhere, in which situation may sometimes be observed five or more tiers one above the other, as at Pisa cathedral, and in other examples, in which the front is literally covered with them. There is another peculiarity observable in the arrangement of these arcades, where they run under gables or raking cornices; for in such cases the arcades follow the line of the gable, the arches rising in succession one above another; and this is effected either by raising the shafts which support the arches on steps rising with the slope of the roof, or else by elongating the shafts as they approach the apex, their bases being upon the same horizontal line. These arches are supported on shafts, either plain or ornamented, with capitals and bases, the arches likewise being with or without archivolts: sometimes the arcade itself and the spandrels are elaborately enriched. This peculiar arrangement of arcades under the gable, forms a very decided characteristic of the style, such decoration being generally found in this part of the building, if nowhere else: another position in which it is commonly seen, is round the angular or semicircular apsides which were frequent at the east end of churches in this style; but we not unfrequently find the same decoration employed on the sides of the building, covering the entire surface of wall as at Pisa cathedral. Corbel-tables at the top of the walls immediately under the roof, are also very common, and these again follow the same rule as arcades when carried under a gable; they are generally formed of a series of very small arches, sometimes interlaced, so as to present a scolloped appearance underneath. Each story of a building is generally marked by a horizontal string-course.

The face of the wall, whether ornamented with arcades or left plain, but more especially in the latter case, is generally divided into panels as it were by pilasters or buttresses, if we may so term them, being carried vertically up the face of the building without interruption, and projecting slightly in front of the general surface of the wall. Such projecting strips of wall are generally plain, but sometimes very much ornamented, as in the front of San Michele at Pavia. They are very narrow in comparison to their height, except at the angles of buildings, where they are usually wider; they reach also from the top to the bottom of the building, breaking through horizontal cornices, arcades, and anything which comes in their way, all of which are for the most part stopped by them, except the corbel table into which they merge, the surfaces of both being flush. They certainly give an appearance of strength, especially when placed at the angles, and resemble buttresses to some extent, but probably were not intended to serve their purpose; they would appear to be added rather for ornament than for any other end, as they are too shallow to afford much real strength to the walls.

Pinnacles are by no means frequent, and when present have the appearance of being set on the part they rise above, from which they are divided by horizontal string-courses; they are also very low, and look more like pedestals than pinnacles.

Windows in this style are generally very narrow, and sometimes mere slits. They consist of one, two, or more lights divided by shafts, and having semicircular heads. Where there are more than two lights, the centre one is not unfrequently higher than the others, and the whole are often included under one larger arch. At a late period in the style we find wheel or circular windows common in the west façades; they are composed of spokes radiating from a centre, connected at the further extremities by small arches, and enclosed within a moulded circle. These windows were first introduced in this style, and though adopted in later styles, may be said to be characteristic of Lombardic architecture.

While windows were sparingly introduced, and of small dimensions, and at the same time seldom enriched, so as to contribute but slightly towards the embellishment of the buildings; doorways, on the other hand, became important features, and were much decorated. The aperture was mostly plain and square-headed, but it was enclosed in a recess formed by a series of arches standing one behind and within the other, and supported upon columns. The spandrel also above the openings, was sometimes enriched with sculpture. The dressing to the doorway was occasionally so deep as to be nearly as wide at the opening. The façade had frequently a central and two side doors.

The stone used in the construction of the walls, consisted of comparatively small blocks, but these were well tooled and put together. In the latter part of the eleventh century, the walls were composed of alternate courses of materials of different colours; sometimes stone alternating with marble, and sometimes marbles of different hues being employed in the same manner. The walls were often white and black, and sometimes red and brown. During the twelfth century, brick was in general use, but still preserved the same parti-coloured appearance, by alternating with stone or marble. It is not improbable that this practice was borrowed from the Saracens.

In the eleventh century, another feature of some importance and character was introduced, which was a projecting porch of imposing appearance, some such porches consisting of two stories in height. They had a large arched aperture, and were usually covered with a vaulted roof supported on pillars, of which the two foremost rested on the back of lions or other animals, a feature which is characteristic of the style. Some of these porches are of the most elaborate description.

In the interior of churches, the peculiarities of style are not so readily observed, but are to be sought for rather in matters of detail, which are equally observable on the exterior. The arrangement is much the same as in the preceding methods of building. The plan is usually if not universally cruciform, the intersection of the two arms of the cross being covered by an octagonal or circular dome, somewhat similar to the Byzantine practice; but the shape of the cross generally differs from the Byzantine, in having one of the arms longer than the other, whereas, in the other case, the arms are all of equal length. Hence one form is termed the Greek, the other the Latin cross. Here we observe a mixture of the Byzantine and Roman styles, the dome of the one and the ground plan of the other being combined, and this is not the only particular in which the combination of the two styles is observable; the triforia, which are common in Lombardic churches, are an emanation from the Byzantine, while a great many minor features are essentially Roman. The east end is for the most part terminated in an apse, either semicircular or octagonal, as are also occasionally the aisles. Crypts are seldom omitted. The windows, as we before observed, are of small dimensions, and hence the buildings have a somewhat gloomy appearance in the interior.

In matters of detail are to be found some of the principal characteristics of the style. The shape of the arch still remains for the most part semicircular, but other forms are also found; such are the horse-shoe, the trefoiled, and stilted

arch, the last being by no means uncommon, especially in the external arcades which run beneath the gable. In some instances, the stilting is effected by raising the arch on one or more blocks or abaci, placed upon the capitals of the columns, and upon these blocks again are sometimes added small heads or masks, so as to fill up the space between the arches, and continue the vertical line of the columns. Such abaci are not ungraceful, for they give a greater appearance of strength to the construction, than if the arch sprung immediately from the capital; the practice of stilting also has its advantages, in adding to the importance of small arches, which being narrow, would appear depressed and heavy if mere semicircles. Large arches were mostly semicircular, and differed from those of the preceding period, inasmuch as they sprang directly from the columns, without the intervention of entablature or architrave. It is true this practice had been introduced once or twice in the Roman examples, but it was not by any means common, and even in cases where the entablature was omitted, there was usually a square block between the arch and the capital. Two or more arches are frequently included under one common arch, the smaller ones being separated by small shafts: the same arrangement is not uncommon in Byzantine architecture. Arches were very often perfectly plain, without archivolt mouldings of any kind, but not unfrequently finished with an archivolt, which consisted either of a simple moulding enclosing a plain band round the arch, or else divided into faciæ, and otherwise enriched. Arched corbel-tables were very frequently employed, and the arch used for every purpose of decoration. Compound arches, consisting of a series, placed in recession one behind and projecting beyond the other, are frequent in this style.

The bases of pillars were sometimes mere blocks, round at the summit, and square at the sides, but frequently moulded in rude imitation of the Attic base. Sometimes, as we observed in speaking of projecting porches, the pillars were supported on figures of animals, and this peculiarity is almost confined to this situation, but we have examples of it in other positions; at Worms' cathedral, an entire colonnade is supported in this manner. It has been suggested that the use of this kind of base was occasioned by the employment of materials and fragments taken from the ruins of more ancient edifices, where columns being found too short for their intended situation, were raised or stilted up by being set on other fragments, for which purpose remains of sculpture may have been adopted, either because they chanced to be at hand, or because considered more ornamental, and as adding richness to the column itself, and it is supposed that this irregularity, thus occasioned in the first instance, grew by degrees to be a matter of taste, and was adopted out of choice. This supposition is ingenious, and not without some show of reason on its side; but if such were indeed the case, it would seem strange that this practice was not adopted earlier, for it is a characteristic of late work, and seems to be almost peculiar to the projecting porches, which were not introduced for two centuries after the commencement of Lombardic architecture. The fact of such columns being almost invariably found in this situation, and seldom in any other, would give some weight to the supposition which discovers their origin and use in symbolism, the two lions being placed at the entrance as the guardians of the church, or else as representing the strength and vigilance of the church.

The shafts were of various shapes and proportions, they are by far the most frequently cylindrical, without being tapered, but some few examples of tapered shafts are to be found, which are probably of an early date. Instances of fancifully-shaped and decorated shafts are not uncommon, especially in the smaller columns, or such as are applied to merely ornamental purposes. Of these, some are polygonal in plan, some fluted or reeded, some twisted or cut into spiral grooves or mouldings, of which some consists of more than one slender shaft rising from a common base, and twisted round each other as they rise, and others of a single shaft twisted like a spiral: other examples again are zigzagged horizontally, and sculptured in various devices. Tall slender shafts are not unfrequently banded in the middle.

Capitals are of equal diversity, and sometimes there are scarcely to be found two capitals of the same design in one building. They were frequently formed of foliage; and these, as regards the general mass and outline, and also the decoration, bear some resemblance to the Corinthian: the foliage, however, is usually of a more stiff and formal character than the classic, more heavy, and not so graceful. Scroll-work is frequently introduced, as a means of ornamentation for capitals; monsters, too, and grotesque and other images, are so commonly used for this purpose, as to become characteristic of the style. Some capitals, however, are nearly plain, and these are often in the shape of an inverted cone, cut so as to present four flat faces, which are occasionally more or less ornamented. Monstrous imagery was very prevalent in this and other situations, until the eleventh century, when a more classical taste prevailed, and figures of dragons and demons gave way to sculpture of a more graceful design this remark applies, however, only to the south of Italy.

The bulk of columns had no reference to the height, as we find pillars of all proportions, from the low, stunted shaft to the long, slender moulding, as it may be termed; the pilasters on the external walls are often so slender, in proportion to their height, as to have the appearance of mere strips; and half-columns of a similar proportion are not unfrequently carried up the internal walls, to support the vaulting. Columns are often single, especially when massive, but they are not unfrequently doubled in breadth or depth, and sometimes quadrupled. Compound piers, in lieu of single columns, are of very common occurrence, and serve to distinguish this from preceding styles; such arrangement is very usual where great strength is required, and clustered columns are not unfrequently placed against walls. Nook-shafts are common in doors, windows, and other apertures, as are also edge-shafts.

Buttresses are not employed in this style, unless indeed we choose to apply the term to the slightly projecting strips or pilasters which appear to divide the walls into panels.

There is one feature common to Lombardic churches, of which we have not taken notice; it is the campanile, or bell-tower, which was a common and picturesque addition. There is a remarkable difference in the design of these towers in the different parts of Italy; at Ravenna they are cylindrical, with a horizontal string-course at each floor, some of which are lighted by single round windows, others by clusters of two or three: they have low roofs. At Venice all the steeples are square, and without string-courses, each side being divided into two or three panels running uninterruptedly from base to top. At Rome such towers are square, but have horizontal string-courses, the divisions or stories between each two having a number of small arches with or without columns. These towers have low roofs.

Having now given a rapid sketch of the main features and peculiarities of the style under consideration, it will be well to give a short description of a few of the more remarkable examples executed in that style; and in this division, as well as in the preceding, we must express ourselves greatly indebted to the standard works of Gally Knight and Hope, on the subject, to which works we would also refer the

reader for more detailed information and more copious illustrations. The former work is beautifully got up.

The church of San Michele, at Pavia, is of the basilican plan, and is provided with transepts; it measures 189 feet in length by 81 in extreme width, the nave being 45 feet wide. The chancel has a semicircular apse, and is approached by several steps, and beneath it is a crypt, a very common addition to Lombardic churches. Above the intersection of nave and transept rises a Byzantine cupola. "The walls of the building are of stone, massive and thick, and on the exterior are ornamented, with small open galleries, which follow the shape of the gable in front, and crown the semicircular apse. The portals are covered with imagery, nor are the ornaments confined to the portals. Bands enriched with imagery are carved along the whole of the front, and modillions are let into the walls. The windows are round-headed, and are divided by small pillars. The drum of the dome is enriched externally with two tiers of arcades.

In the interior, the arches on either side of the nave are supported by compound piers, all the capitals of which are enriched with capitals and symbols. Above the aisles, on each side of the nave, is a triforium, and, above it, the roof is vaulted in stone, but the pilasters which run up to support the vault are of later character than the older portions of the building, and confirm the impression suggested by the nature of the roof itself, that the present vaulted roof must have been substituted for an older roof of wood.

The plan of San Thomaso in limine is circular, and on the exterior, the walls are divided into compartments by pilasters, and have an arcaded corbel-table under the roof. A rectangular portion projects from the circle, and is terminated by a semicircular apse, which is decorated in a similar manner to the other part of the church. Above the circular part rises a dome, which is not supported by pendentives, but by a drum or circular wall rising above the roof: the whole is surmounted by a cupola. The windows throughout are small and insignificant. Internally, the drum of the dome is supported on eight pillars, which are simple, round, and stunted with capitals grotesquely carved; the arches spring immediately from the capitals. The walls are very thick.

The church of San Ambrogio, Milan, is a very good example. The plan is basilican, the arcade of the nave being supported on compound piers, above which runs an arcaded corbel-table, and above this again a triforium, the arches being supported on very stunted compound pillars. The roof is vaulted with the pointed arch, but this is of late date. The capitals of the arches are almost, in all cases, foliated, and there is considerable freedom from the monstrous imagery usually apparent. This is one of the few churches which retains the atrium, which consists of an arcade resting on a series of compound pillars with capitals, and covered with a roof, under which is an arcaded corbel-table.

S. Geron's church presents a somewhat curious plan, consisting of a vast circular vestibule, with a rectangular nave behind it, terminating in a semicircular apse, on each side, and a little in front of which is a campanile. Above the circle rises an octagonal cupola, the supporting pillars of which are prolonged upwards in ribs, which, centering at the summit, meet at one point. Opposite the entrance, in the interior, are steps leading to the church, at the further end of which are steps leading to the apse or altar. In the baptistery and vestry are steps leading to the area between the two high square towers, and to the roof of the apse, over the semicircular east end, which is belted round, as well as the cupola, by galleries with small arches, and pillars on a panelled balustrade. The entrance-door at the vestibule has a square lintel, low pediment, and pointed arch, which are elegant, and the crypts show some remains of handsome mosaics; but the porphyry columns were carried away by the French. Several of the finishings in the interior are pointed.

The Cathedral of Pisa is a very remarkable building, erected during the latter half of the eleventh century; and although it presents to us features of the Lombard style on the exterior, in the interior the details approach more nearly to the Roman, the columns being all simple, and finished with Corinthian caps; the style, too, is throughout the interior more simple than that of Lombardic buildings in general. The plan is that of a Latin cross, having two aisles on each side of the nave transepts, and a cupola over the intersection. The colonnade on each side of the nave consists of 12 columns of a single block of marble, and of 24 feet 10 inches in height, and 2 feet 3 inches in diameter, with Corinthian capitals skilfully worked. The total height, including capitals and base, is 30 feet 10 inches. An architrave is carried all along the nave above the arches, which spring from the capitals, and above this is a triforium consisting of a series of arcades, each arch containing two arched apertures divided by a shaft with Corinthian capital. Above the triforium is a clere-story of semicircular-headed windows. The four aisles have also Corinthian columns, but they are much smaller, and raised on plinths. The walls are composed of alternate courses of red and white marble. The width of nave and four aisles is 106 feet, of the nave 41 feet, the total internal length 311 feet, and the width across the transepts 237 feet 4 inches; the width of the transepts, with its aisles, 58 feet, height of nave 91 feet, of transept 84, of aisles 35 feet. In the centre of the nave are four piers, from which rise four large arches supporting the elliptical cupola.

On the exterior, the entire church is raised upon a series of steps which gives increased grandeur to its magnificent elevation. The width of the western façade is no less than 116 feet, and its height 112 feet. It comprises five stories, of which the first or lowermost consists of seven arches supported by six Corinthian columns and two pilasters, the middle arch being larger than the others. There are three entrances or doorways in the central and alternate arches. The second story contains twenty-one arches supported by twenty columns and two pilasters. At the third story the façade contracts where the two aisles finish, and form two lateral inclined planes, whence towards the centre are columns with arches on them as below, but the columns on each side under the inclined planes gradually diminish in height. The fourth story is contracted, and contains only eight arches similar to those below. The fifth forms the pediment, and consists likewise of eight arches, the columns which support them gradually diminishing in height as they recede from the centre. The sides all round the building have two orders of pilasters one above the other. The roof of the nave is supported externally by a wall decorated with columns and arches; and the drum of the cupola is enriched with eighty-eight columns and arches, each of which is surmounted by a pediment.

The Duomo Modena is a good specimen of the Lombard style, and belongs to the close of the 11th century. "External arcades ornament both the west end and the great semicircular apse. In the interior, monsters and grotesque images are still retained in the capitals of some of the pillars. But a feature which is not found in old Lombard churches, may be remarked here, in a large projecting porch two stories in height, which advances before the principal entrance; and in the lions, on the backs of which the pillars of the porch repose. Though projecting porches were an essential part of the primitive churches, they seem to have been abandoned

under the Lombard dynasty, and not to have been resumed till the 11th century, when they became universal. The lions are symbolical. They were intended to represent the strength and vigilance of the church. At a later period, the animals which were introduced in the porches, often represented the arms of the state to which the building belonged." "On either side of the nave of this cathedral are galleries. Under the chancel there is a lofty crypt, the chancel being approached by several steps, as at San Miniato and other churches."

The campanile is 315 feet high, and is one of the four towers of which the north of Italy has reason to be proud. The date is uncertain, but the tower must have been complete in the early part of the 13th century. The upper portion is of later date.

S. Zenone, Verona, was finished in the latter part of the 12th century, and forms a fair specimen of the style. The plan is that of a Latin basilica, without transepts. The walls are constructed of alternate courses of marble and brick, but the façade is entirely of marble. The entire face of the building is divided vertically into bays by long strips or pilasters, and horizontally by arched corbel-tables and arcades. The façade is remarkable for containing one of the earliest specimens of wheel-windows, as also for a very rich projecting porch, profusely decorated with sculpture. There is a good bas-relief within the portal over the door. The pillars as usual rest on the backs of lions. In the interior the nave is divided from the aisles by an arcade, each bay containing two arches supported by a central single shaft, and by compound shafts at the sides, so that pillars and piers alternate in the length of the arcade; the capitals of the single shafts still retain the monstrous imagery of an earlier period. There is no triforium, and the clere-story is lighted by small windows. There is a campanile, of somewhat later date.

San Michele, Lucca, is a very rich example of the Lombard style, but although the building itself is of early date, the enrichments are much later. The principal feature is the enriched façade which was added in 1188 by Guidetto. It is somewhat similar to the façade of Pisa cathedral, but of a more florid description. The lower story is ornamented with attached arcades, and above this are four tiers of galleries with detached arcades, the shafts, capitals, archivolts, and spandrels being enriched with elaborate carving. In the third gallery is a rose window. The sides of the building contain two tiers of arcades, of which the upper one was added at a late period, and is of very good design.

For further particulars on this subject, we must refer to Saxon, Norman, and Romanesque Architecture.

LONGIMETRY, (from the Latin, *longus*, length, and Greek, *μετρέω*, *to measure*,) the art of measuring lengths, accessible and inaccessible.

LOOP HOLES, the small narrow windows in castellated buildings, from which to discharge missiles. They were usual near entrances, and sometimes on the merlons of the battlement. They are sometimes in the shape of a cross, and usually have a circular enlargement at top and bottom, and sometimes in the middle. When splayed, they were also used to give light.

LORME, PHILIBERT DE, an eminent French architect, born at Lyons, in the early part of the sixteenth century. He went to Italy when he was but fourteen years of age, to study the art for which he seemed to have a natural taste, and there his assiduity attracted the notice of Cardinal Cervino, afterwards Pope Marcellus II., who took him into his palace, and assisted him in his pursuits. He returned to France in 1536, and was the means of banishing the Gothic taste in buildings, and substituting in its place the Grecian. He was employed by Henry II., for whom he planned the Horseshoe at Fontainebleau, and the châteaus of Anet and Meudon. After the demise of that king, he was made inspector of the royal buildings by Catharine de Medicis; and, under her direction, he repaired and augmented several of the royal residences, and began the building of the Tuileries. In 1555 he was created counsellor and almoner in ordinary to the king; and, as a recompense for his services, he was presented with two abbacies. These honours, it is said, made him arrogant, which occasioned the poet Ronsard to satirize him in a piece, entitled *La Truelle Crossée*, or "The Croziered Trowel." De Lorme took his revenge, and shut the garden of the Tuileries against him; but the queen took part with the poet, and severely reprimanded the reverend architect. De Lorme died in 1577. He published *Dix Livres d' Architecture*, and *Nouvelles Inventions pour bien Bâtir et à petits Frais*.

LOUVRE, a turret or lantern on the top of roofs, open to the interior of the building, and also to the external air by means of apertures in the sides. They were formerly used for carrying off the smoke, when the hearth was in the centre of the hall; probably also for ventilation in general.

LOZENGE, (from the French,) a quadrilateral figure of four equal sides with oblique angles.

Lozenge Moulding, a moulding in the shape of a lozenge, common in Norman work.

LUCULLEUM MARMOR, a hard stony kind of marble, of a good fine black, and capable of an elegant polish, but little regarded from its want of variegations. When fresh broken, it is seen to be full of small but very bright shining particles, appearing like so many small spangles of talc. It had its name from the Roman consul Lucullus, who first brought it into use in that city. It is common in Italy, Germany, and France. We have much of it imported, and our artificers call it the *Namur marble*; the Spaniards call it *marble of Buga*.

LUFFER BOARDING, a series of boards placed in an aperture so as to admit air into the interior, but to exclude rain. It is frequently used in lanterns. A very celebrated one is that upon the church of St. Martin Outwich, in Bishopsgate-street, opposite the City of London Tavern. The plan is circular, and the apertures four in number, with pilasters between them.

LUNE, or Lunula, (from the Latin, *luna*, the moon,) the space between two unequal arcs of a circle.

LUNETTE, (French,) apertures in a cylindric, cylindroidic, or spherical ceiling, the head of the aperture being also cylindric or cylindroidic, as the upper lights in the nave of St. Paul's Cathedral.

LUTHERN, (from the Latin *lucerna*, light or lantern,) a kind of window over the cornice in the roof of a building, standing perpendicularly over the naked of the wall, and serving to illuminate the upper story.

The French architects distinguish them into various forms, as square, semicircular, bull's eyes, flat arches, and Flemish.

LYCH-GATE, or Lich-Gate, a covered gate at the entrance of church-yards, at which the bier was rested.

LYING PANELS, those in which the fibres of the wood are placed horizontally.

M.

MACHICOLATIONS, openings made through the roofs of portals to the floor above, or in the floors of projecting galleries, for the purposes of defence, by pouring through them boiling lead, pitch, &c., upon the enemy. In the galleries they are formed by the parapet, or breast-work, being set out on corbels beyond the face of the wall, the spaces between that open throughout are the machicolations. From its striking appearance, the corbelled parapet was frequently used where machicolations were not required for the purposes of defence, and the apertures so called were omitted. Machicolations do not appear to have been used earlier than the end of the twelfth century.

MACHINE, signifies anything used to augment or to regulate moving forces or powers; or it is any instrument employed to produce motion, in order to save either time or force. The word is of Greek origin, and implies *machine, invention, art;* it is therefore properly applied to any agent, in which these are combined, whatever may be the strength or solidity of the materials of which it is composed. The term *machine* is, however, generally restricted to a certain class of agents, which seem to hold a middle place between the most simple tools or instruments, and the more complicated and powerful engines; this distinction, however, has no place in a scientific point of view; all such compound agents being generally classed under the term *machines*, the simple parts of which they are compounded being termed Mechanical Powers.

Machines are again classed under different denominations, according to the agents by which they are put in motion, the purposes they are intended to effect, or the art in which they are employed, as—*Electric, Hydraulic, Pneumatic, Military, Architectural*, &c., Machines.

The maximum effect of machines, is the greatest effect which can be produced by them. In all machines, working with a uniform motion, there is a certain velocity and a certain load of resistance that yield the greatest effect, and which are therefore more advantageous than any other. A machine may be so heavily charged, that the motion resulting from the application of any given power will be only sufficient to overcome it; and if any motion ensue, it will be very trifling, and the effect small. Again, if the machine is very lightly loaded, it may give great velocity to the load; but, from the smallness of its quantity, the effect may still be very considerable, consequently between these two loads there must be some intermediate one that will render the effect the greatest possible. And this is equally true in the application of animal strength, as in machines, and both have been submitted to strict mathematical investigation, the former being founded on numerous experiments and observations on the best method of applying animal strength, and the measure of it when applied in different directions.

MADERNO, CHARLES, an eminent Italian architect, born at Bissona, in Lombardy, in 1556. He went at a very early age to Rome, where his uncle, Dominico Fontana, was at that time in full employment as an architect. His genius for sculpture became manifest, and he was placed with an artist in that branch of the fine arts. His progress in modelling was such as led his uncle to confide to him the management of some buildings then in hand, which he executed with so much skill, that he was advised to devote himself entirely to architecture. On the death of Sixtus V., Maderno was appointed to design and execute the magnificent tomb for his interment. The public works which were carried on under Clement VIII. were chiefly committed to the care of this artist, and so high was his reputation in the succeeding pontificate, that, on the succession of Paul V. in 1605, he was appointed to finish the building of St. Peter's; his plans being preferred to those of eight competitors, and the work was placed under his direction. He was afterwards employed upon the pontifical palace on the Quirinal mount. Another work, for which he is celebrated, was the raising a fine fluted column found in the ruins of the Temple of Peace, and placing it on a marble pedestal in the square of St. Maria Maggiore. His genius was by no means confined to architecture, he was sent by the pope on a commission to examine the ports of the Ecclesiastical States, and afterwards surveyed the lake of Perugia, and surrounding country, in order to divert the inundations of the river Chiana. He was consulted upon most of the great edifices undertaken in his time in France and Spain, as well as in the principal towns of Italy. His last work of consequence was the Barberini palace of Urban VIII., which he did not live to complete. He died of the stone in 1629, when he had attained to the age of seventy-three. He had seen ten popes, by most of whom he had been regarded with favour.

MAGAZINE, *Powder*, a building constructed for keeping large quantities of powder. These magazines were formerly towers erected in the town-walls; but many inconveniences attending this situation of them, they are now placed in different parts of the town. They were at first constructed with Gothic arches; but M. Vauban, finding these too weak, constructed them in a semicircular form, of the following dimensions: 60 feet long within, and 25 broad; the foundation 8 or 9 feet thick; and 8 feet high from the foundation to the spring of the arch; the floor about two feet from the ground, to prevent damp; and consequently six feet for the height of the story.

The thinnest part, or haunch of the arch, is three feet thick, and the arch made of four lesser ones one over the other, the outside of the whole terminating in a slope to form the roof; from the highest part of the arch to the ridge is eight feet, which makes the angle somewhat greater than ninety degrees; the two wings, or gable ends, are four feet thick, raised a little higher than the roof, as is customary in other buildings: the foundations are five feet thick, and as deep as the nature of the ground required. The piers, or long sides, are supported by four counterforts, each six feet broad, and four feet long, and their interval twelve feet; between the intervals of the counterforts are air-holes, in order to keep the magazine dry, and free from dampness; the dices of these air-holes are commonly a foot and a half every way, and the vacant round them three inches, the insides and outsides being in the same direction. The dices serve to prevent an enemy from throwing fire in to burn the magazine; and, for a farther precaution, it is necessary to stop these holes with several iron plates, that have small holes in them like a skimmer, otherwise fire might be tied to the tail of some small animal, and so drive it in that way; this would be no hard matter to do, since, where this precaution had

been neglected, egg-shells have been found within, that have been carried there by weasels.

To keep the floor from dampness, beams are laid lengthwise, and to prevent these beams from being soon rotten, large stones are laid under them; these beams are eight or nine inches square, or rather ten high and eight broad, which is better, and eighteen inches distant from each other; their interval is filled with dry sea-coal, or chips of dry stones; over these beams are others laid crosswise, four inches broad and five high, which are covered with two-inch planks.

M. Belidor would have brick walls made under the floor, instead of beams, and a double floor laid on the cross-beams; but the plan above described is, we think, preferable.

To give light to the magazine, a window is made in each wing, which is shut up by two shutters of two or three inches thick, one within and the other without it; that which is on the outside is covered with an iron plate, and is fastened with bolts, as well as that on the inside. These windows are made very high, for fear of accidents, and are opened by means of a ladder, to give air to the magazine in fine dry weather.

There is likewise a double door, made of strong planks, the one opens on the outside, and the other within; the outside one is also covered with an iron plate, and both are locked by a strong double lock; the store-keeper has the key of the outside, and the governor that of the inside: the door ought to face the south nearly, if possible, in order to render the magazine as light as can be, and that the wind blowing in may be dry and warm. Sometimes a wall of ten feet high is built round the magazine about twelve feet distant from it to prevent anything from approaching it without being seen. Mr. Muller has proposed some alterations, by way of improvement, in M. Vauban's construction.

If large magazines are required, the piers or side walls which support the arch should be ten feet thick, seventy-two feet long, and twenty-five feet high; the middle wall, which supports the two small arches of the ground floor, eight feet high, and eighteen inches thick, and likewise the arches: the thickness of the great arch should be three feet six inches, and the counterforts, as well as the air-holes, the same as before. Magazines of this kind should not be erected in fortified towns, but in some inland part of the country near the capital, where no enemy is expected.

It has been observed, that after the centres of semicircular arches are struck, they settle at the crown and rise up at the haunches; now, as this shrinking of the arches must be attended with ill consequences, by breaking the texture of the cement after it has been partly dried, and also by opening the joints of the voussoirs at one end, Dr. Hutton proposed to remedy this inconvenience, with regard to bridges, by the arch of equilibration; and as the ill effect is much greater in powder magazines, he also proposed to find an arch of equilibration for them also; and to construct it when the span is twenty feet, the pitch or height ten, which are the same dimensions as those of the semicircle, the inclined exterior walls, at top, forming an angle of 113°, and the height of their angular point above the top of the arch equal to seven feet; this curious question was answered, in 1775, by the Rev. Mr. Wildbore, and the solution of it may be found in Hutton's *Miscellanea Mathematica*.

MAHOGANY, the beautiful reddish-brown coloured wood, of which household furniture is now chiefly made. It is a native of the warmest parts of America and the West Indies. It thrives in most soils in the tropical climates, but varies in texture and grain according to the nature of the soil. On rocks it is of a smaller size, but very hard and weighty, of a close grain, and beautifully shaded; while the produce of the low and richer lands is observed to be more light and porous, of a paler colour, and open grain; and that of mixed soils, to hold a medium of both.

The mahogany-tree is stated to be of very rapid growth, and makes a very fine appearance. Its trunk often exceeds 40 feet in length, and 6 feet in diameter. The Honduras mahogany is cut down at two periods in the year; that is, at Christmas, and in the autumn; the trees are cut off at about 12 feet from the ground, the workmen having a stage to work upon. The trunk furnishes wood of the largest dimensions; but for ornamental purposes, the branches are preferable, the grain in them being closer and the veins more variegated. Mahogany was first brought to London in the year 1724.

In a dry state, mahogany is very durable, and not subject to worms. It does not last long when exposed to the weather. It is a kind of wood that would make excellent timbers for floors, roofs, &c., but on account of its price its use is chiefly confined to furniture and doors for rooms, for which purposes it is the material most in use. It is sometimes used for some parts of window-frames, and for sashes, but from its not standing the weather well, it is not so fit for these purposes. It has also been extensively used in the framing of machinery for cotton-mills, &c.

The variety called Spanish mahogany, is imported from Cuba, Jamaica, Hispaniola, and some other of the West India islands, and in smaller logs than the Honduras. The size of the logs is in general about 20 to 26 inches square, and about 10 feet in length. The Spanish mahogany is close-grained and hard, generally of a darker colour than Honduras; free from black specks, and sometimes strongly figured; and its pores appear as if chalk had been rubbed into them.

The Honduras mahogany is imported in logs of a larger size, that is, from 2 to 4 feet square, and 12 or 14 feet in length; sometimes planks have been got 6 or 7 feet wide. The grain of the Honduras kind is generally very open, and often irregular, with black or gray spots. The veins and figures are frequently very fine and showy; the best kind is that which is most free from gray specks, and of a fine golden colour. It holds with glue better than any other wood.

The cohesive force of a square inch of Spanish mahogany is 7560 pounds, and of Honduras mahogany 11475 pounds.

The weight of the modulus of elasticity of mahogany, is 1,255,500 pounds, for a square inch for Spanish; and 4,593,000 for Honduras. The weight of a cubic foot of mahogany is from 35 to 53 pounds. Representing the—

Strength of oak by 100,	that of Span. mahog. is 67;	of Honduras is 96.
Stiffness of oak by 100,	73;	93.
Toughness of oak by 100	61;	99.

MAIN COUPLES. *See* COUPLES.

MALLET, (from the Latin *malleus*) a large kind of hammer, made of wood, much used by artificers who work with a chisel, as stone-cutters, masons, carpenters, joiners, &c.

MANSARD ROOF. *See* CURB ROOF. The word is derived from Mansart, the inventor.

MANSART, FRANCIS, an eminent French architect, born at Paris in 1598, was son of the king's carpenter, and received those instructions which led him to eminence as an architect, from the celebrated Gautier; but for the high rank to whice he attained in his profession, he was indebted to the force of his own genius. His taste and judgment, united with a fertile imagination and sublime ideas, enabled him to equal the greatest masters in his plans; he was, however, too apt to alter his designs, and even, in aiming at perfection, to demolish what was already not only well done, but scarcely

to be surpassed. This character was the means of preventing him the honour of finishing the fine abbey of Val-de-Grace, founded by Anne of Austria, which he had commenced in 1645, and which, when raised to the first story, the queen put into other hands, to prevent its destruction by him who had reared it. He was employed by the president Longueil to build his great Château des Maisons, near St. Germain's; and, when a considerable part of it was erected, he pulled it down again, without acquainting the master with his intentions. After this, it is to his credit, that he finished it in a very noble style, and it is reckoned one of the finest architectural monuments of that age. A better idea cannot be given of his character than this: Colbert applied to him for a design of the principal front of the Louvre, and Mansart produced many sketches of great beauty, but when told he must fix upon one to be invariably followed, if approved, he declined the business. His last work was the portal of the Minims in the Place Royale; he died in 1666, at the age of sixty-nine. He is known as the inventor of a particular kind of roof, called the *mansarde*. He had a nephew, Jules-Hardouin, who was also eminent in his profession as an architect, and was educated by his uncle. He became a favourite of Louis XIV., and was enabled, under his patronage, to realize a large fortune. Some of his principal works were the Château de Clugny, the palace of Versailles, the house of St. Cyr, the gallery of the Palais Royal, the places of Louis-le Grand and des Victoires, and the dome and finishing of the Invalides. He died suddenly at Marly, in the year 1708.

MANSION, (from the Latin *mansio*, an inn) a dwelling-house, or habitation, especially in the country. Among the ancient Romans, *mansio* was a place appointed for the lodging of the princes, or soldiers, in their journey; and in this sense we read *primum mansionem*, &c. It is with us most commonly used for the lord's chief dwelling-house within his fee, otherwise called the capital messuage, or manor-place: and mansion-house is taken in law for any house or dwelling of another, in case of committing burglary, &c.

MANTLE-TREE, or MANTEL-TREE, (from the Welsh) the lower part of the breast of a chimney; formerly consisting of a piece of timber, laid across the jambs, for supporting the breastwork; but, by a late act of parliament, chimney-breasts are not to be supported by a wooden mantle-tree, or turning piece, but by an iron bar, or brick or stone arch.

MARBLE, a variety of lime-stone, of so compact a texture as to admit of a beautiful polish. The different kinds of marble are infinite, therefore any attempt to describe them in detail would necessarily occupy much more space than we can allow to this article: they all agree in being opaque, excepting the white, which becomes transparent when cut into thin pieces. In the Borghese palace, at Rome, are some specimens of marble exquisitely white, so flexible, that if poised horizontally on any resisting body placed on a plane, a salient curve will be formed by the two ends touching the plane. A similar property is acquired in a small degree by statuary marbles exposed to the action of the sun, which no doubt weakens the adhesion of the particles. It is this which frequently occasions the exfoliation of projecting parts, and the artist would do well to ascertain, by experiments, the kind of marble that has the least tendency to this desiccation.

The greater part of the quarries, which supplied the ancients with marble, are entirely unknown; in the Napoleon Museum are preserved the most exquisite specimens of many of them, the grand repositories of which are consigned to oblivion, unless chance should guide some penetrating eye to their dark recesses.

Da Costa, in his "Natural History of Fossils," gives a large catalogue of marbles, disposed in a methodical order, which we shall follow in the following brief notices of this extensive subject:—

Division I.—Marbles of one plain colour.

Section 1.—Black marbles. Most of these contain bitumen, and are fetid when bruised.

Examples.—The Namur Marble, the marble of Ashford in Derbyshire, Dent in Yorkshire, near Crickhowell, Tenby, Kilkenny, &c. The marble, anciently called Marmor Luculleum, and now Nero Antico.

Section 2.—White Marbles.

Examples.—The marble of Poros, in which the Laocoon and Antinous are executed; the Carrara marble, of finer grain, much used in modern sculpture; the Skye marble, noticed by Dr. MacCulloch; that of Inverary, Assyut, Blair Athol, &c.

Section 3.—Ash and gray marbles.

Examples.—A beautiful marble, of compact oolitic texture, at Orelton, near the Clee Hills, in Shropshire, deserves mention.

Section 4.—Brown and red marbles.

Examples.—The Rosso Antico, a rival to which, at least in colour, has been found on the estate of the Duke of Devonshire, near Buxton. The mottled brown marble of Beetham Fell, near Milnthorp, is of good quality.

Section 5.—Yellow marbles.

Example.—The Giallo Antico. Siena marble, also dug at Mafra, near Lisbon. That used in ancient Rome is said to be from Numidia.

Section 6.—Blue marbles.

Example.—Near St. Pons, in Languedoc.

Section 7.—Green marbles.

Example.—The Marmor Lacedæmonicum of Pliny. It is dug near Verona.

Division II.—Marbles of two colours.

Section 1.—Black marbles, variegated with other colours.

Example.—Near Ashburton, in Devonshire; Torbay, in the same county; Bianco, or Nero Antico, the African Breccia of the ancients; Giallo e Nero Antico.

Section 2.—White marbles, variegated with other colours.

Example.—Marble imported from Italy. Marbles of this general character occur in Siberia; at Plymouth; at Killarney; in Sweden, &c.

Section 3.—Ash and gray marble, variegated with other colours. These are very numerous, and occur in various parts of Europe.

Section 4.—Brown and red marbles, variegated with other colours.

Section 5.—Yellow marbles, variegated with other colours.

Section 6.—Green marbles, variegated with other colours.

Example.—Egyptian marbles. The Marmor Tiberium and Augustum of Pliny; some Verde Antico, as that dug near Susa, in Piedmont; the beautiful marble of Anglesey (called Mona marble); the marble of Kolmerden, in Sweden.

Division III.—Marbles variegated with many colours.

Example.—Some of the Plymouth marble; the beautiful brocatello, or brocade marble, of Italy and Spain.

Marbles containing shells, corals, and other extraneous bodies.

In this division of marbles, the British islands are rich. Some of the Plymouth, Ashburton, and other Devonian limestones, are extremely beautiful, from the abundance of fine corals exquisitely preserved in them; the crinoidal marbles of Flintshire, Derbyshire, and Garsdale in Yorkshire, are elegant examples of the carboniferous limestone; the shell marbles of Rance, Northamptonshire, Buckingham,

Whichwood Forest, Stamford, Yeovil, may be noticed from the oolitic rocks; that of Petworth and Purbeck, from the Wealdon strata, has been extensively used by the architects of the middle ages. In general, the working of the English marbles is costly, and their use limited.

MARBLE, *Polishing of.* The art of cutting and polishing marble was, of course, known to the ancients, whose mode of proceeding appears to have been nearly the same with that employed at present; except, perhaps, that they were unacquainted with those superior mechanical means which now greatly facilitate the labour, and diminish the expense of the articles thus produced.

An essential part of the art of polishing marble is the choice of substances by which the prominent parts are to be removed. The first substance should be the sharpest sand, so as to cut as fast as possible, and this is to be used till the surface becomes perfectly flat. After this the surface is rubbed with a finer sand, and frequently with a third. The next substance after the finest sand is emery, of different degrees in fineness. This is followed by the red powder called tripoli, which owes its cutting quality to the oxide of iron it contains. Common ironstone, powdered and levigated, answers the purpose very well. This last substance gives a tolerably fine polish. This, however, is not deemed sufficient. The last polish is given with putty. After the first process, which merely takes away the inequalities of the surface, the sand employed for preparing it for the emery should be chosen of a uniform quality. If it abounds with some particles harder than the rest, the surface will be liable to be scratched so deep as not to be removed by the emery. In order to get the sand of uniform quality, it should be levigated and washed. The hard particles, being generally of a different specific gravity to the rest, may by this means be separated. This method will be found much superior to that of sifting. The substance by which the sand is rubbed upon the marble is generally an iron plate, especially for the first process. A plate of an alloy of lead and tin is better for the succeeding processes, with the fine sand and emery. The rubbers used for the polishing, or last process, are of coarse linen cloths, such as hop-bagging, wedged tight into an iron plane. In all these processes, a constant supply of small quantities of water is absolutely necessary.

The sawing of marble is performed on the same principle as the first process of polishing. The saw is of soft iron, and is continually supplied with water and the sharpest sand. The sawing, as well as the polishing of small pieces, is performed by hand. The large articles, such as chimney-pieces and large slabs, are manufactured by means of machinery, working by water or steam.

Several patents have been taken out for sawing and polishing marble. In 1822, Sir James Jelf patented a combination of machinery for cutting any description of parallel mouldings upon marble slabs, for ornamental purposes; in which tools, supplied with sand and water, are made to traverse to and fro. Mr. Tullock obtained a patent, in 1824, for improvements in machinery for sawing and grooving marble; and in 1829, Mr. Gibbs, also, for an invention for working ornamental devices in marble.

MARGIN (from the Latin *margo*) of a door or shutter, the surface surrounding the frame between the moulding and the extreme arris which terminates the face.

MARQUETRY (from the French), inlaid work; a curious kind of work, composed of pieces of hard fine wood, of different colours, fastened in thin slices on a ground, and sometimes enriched with other matters, as tortoise-shell, ivory, tin, and brass.

There is another kind of marquetry made, instead of wood, of glasses of various colours; and a third, where nothing but precious stones and the richest marbles are used; but these are more properly called *mosaic work.* The art of inlaying is very ancient, and is supposed to have passed from the east to the west, among the spoils brought by the Romans from Asia. Indeed, it was then but a simple thing; nor did it arrive at any tolerable perfection till the fifteenth century, among the Italians. It seems finally to have arrived at its height in the seventeenth century, among the French.

MASONRY, the art of preparing stones, so as to tooth or indent them into each other, and form regular surfaces, either for shelter, convenience, or defence: as the habitations of men, animals, the protection and shelter of goods, &c.

The chief stone used in London is Portland, which comes from the island of Portland, in Dorsetshire. It is used for public edifices, not only in ornaments, mouldings, and strings, but in all the exterior parts. In private buildings, where brickwork predominates, it is used in strings, window-sills, balusters, steps, copings, &c. It must be observed, however, that under a great pressure it is apt to splinter or flush at the joints, and for this reason the joints cannot be made so close as many other kinds of stones will admit of. When it is recently quarried it is soft, and works easily, but acquires great hardness in length of time. The cathedral of St. Paul, Westminster-bridge, and almost every public edifice in London, are constructed wholly, or in part, of Portland stone.

Purbeck stone comes from the island of Purbeck, in Dorsetshire also. It is mostly employed in rough work, as steps and paving.

Yorkshire stone is also used where strength and durability are requisite, as in paving and coping. Ryegate stone is used for hearths, slabs, and copings.

In Edinburgh, a very fine stone, called Craigleith, brought from a village of the same name, in the neighbourhood of that city, is most commonly used in the construction of edifices. They have also very good stone from the Hails quarry, but rather inferior in point of colour.

The Craigleith quarry produces two kinds of rock, one of a fine cream or buff colour, called the *liver rock*, which is almost unchangeable, even though exposed in a building to the weather.

The city of Glasgow is built of various kinds of stone, the best of which are the Possel and the Lord President's quarry; most other kinds are not only perishable, but liable to change their colour.

In the north of England, stone fit for hewn work is chiefly of a reddish colour. There is a very good white stone, however, in the vicinity of Liverpool, of which several of the public buildings are constructed.

All the stone fit to be squared, or squared and rubbed smooth, for the use of building, is mostly composed of sand. The stone used for the same purposes in the south of England is, in some parts, entirely chalk, and in other parts limestone. The Bath and Oxfordshire stone has so little grit in its texture, as to be wrought into mouldings with planes, as in joinery, and the surfaces are finished with an instrument called *a drag.*

Marbles, with regard to their contexture and variegation of colour, are almost of infinite variety: some are black, some white, some of a dove colour, and others beautifully variegated with every kind of rich colour. The best kind of white marble is that called *statuary*, which, when cut into thin slices, becomes almost transparent, a property the others do not possess. The texture of marble, with regard to working, is not generally understood, even by the best workmen, though upon sight they frequently know whether it will

receive a polish or not. Some marbles are easily wrought, some are very hard, and other kinds resist the tools altogether.

Mortar is another principal material used in cementing the stones of a building. The reader who wishes to obtain a full knowledge of this department of masonry, may consult the articles CEMENT, MORTAR.

Wherever it is intended to build upon, the ground must be tried with an iron crow, or with a hammer: if found to shake, it must be pierced with a borer, such as is used by well-diggers; and if the ground generally prove to be firm, the loose or soft parts, if not very deep, must be excavated until a solid bed appears.

If the ground prove soft in several places to a great depth under apertures, and firm upon the site of the piers, inverted arches must be turned under the apertures, so that if the foundation sink, the arches may resist the re-action of the ground: and then the whole wall will sink uniformly, or descend in one body. And even where the ground is of a uniform texture, it is always eligible to turn inverted arches under apertures, wherever there is a part of a wall carried up from the foundation to the sill of that aperture: it is from neglect in this circumstance, that the sills of windows in the ground-stories of buildings are frequently broken; indeed it is seldom or never otherwise.

Arches adequate to this purpose should rather be of a parabolic form than circular, the figure of the parabola being better adapted to preserve an equilibrium than the arc of a circle, which is of uniform curvature. If unfortunately the soft parts of the ground prove to be the site of the piers, and, consequently, the hard places under the apertures, piers should be built under the apertures, and arches suspended between the piers, with their concave side towards the trench, as usual.

The use of concrete has, however, made a great change in the art of preparing foundations, the general practice now being to excavate the trenches for the footings of the walls, and put in a bed of concrete, on which is laid the masonry.

For more information upon this subject, see the articles FOUNDATION, CONCRETE.

In walling, the bedding joints have most commonly an horizontal position in the face of the work, and this disposition ought always to take place when the top of the wall terminates in an horizontal plane or line. In bridge building, and in the masonry of fence-walls upon inclined surfaces, the bedding-joints on the face sometimes follow the upper surface of the wall or terminating line.

The footings of stone-walls ought to be constructed of large stones, which, if not naturally nearly square, should be reduced by the hammer to that form, and to an equal thickness in the same course; for if the beds of the stones in the foundation taper, the superstructure will be apt to give way, by resting upon mere angles or points with inclined beds instead of horizontal. All the vertical joints of any upper course should break joint, that is, they should fall upon the solid part of the stones in the lower course, and not upon the joints.

When the walls of the superstructure are thin, the stones which compose the foundation may be so disposed, that their length may reach across each course, from one side of the wall to the other. In thicker walls, where the difficulty is greater in procuring stones of sufficient length to reach across the foundation, every second stone in the course may be a whole stone in the breadth, and each interval may consist of two stones of equal breadth, that is, placing header and stretcher alternately. But when those stones cannot be had conveniently, from one side of the wall, lay a header and stretcher alternately, and from the other side lay another series of stone in the same manner, so that the length of each header may be two-thirds, and the breadth of each stretcher one-third of the breadth of the wall, and so that the back of each header may come in contact with the back of an opposite stretcher, and the side of that header come in contact with the side of the header adjoining the said stretcher. In broad foundations, where stones cannot be procured for a length equal to two-thirds of the breadth of the foundation, build the work so that the upright joints of any course may fall on the middle of the length of the stones in the course below, and so that the backs of each stone in any course may fall upon the solid of a stone or stones in the course below.

The foundation should consist of several courses, of which each superior course should be of less breadth than the inferior one, say four inches on each side in ordinary cases, and the upper course project four inches on each side of the wall. The number of courses must be regulated by the weight of the wall, and by the size of the stones of which the foundation consists.

A wall, which is built of unhewn stone, is called a *rubble-wall*, whether with or without mortar. Rubble work is of two kinds, coursed and uncoursed. Coursed rubble is that of which the stones are gauged and dressed by the hammer, and thrown into different heaps, each heap containing stones of the same thickness; then the masonry is laid in courses or horizontal rows, which may be of different thicknesses. The uncoursed rubble is that where the stones are laid promiscuously in the wall, without any attention to placing them in rows. The only preparation which the stones undergo, is that of knocking off the sharp angles with the thick end of the scabbling hammer.

Walls are most commonly built with an ashlar facing, and backed with brick or rubble work. Brick backings are common in London, where brick is cheaper; and stone backing in the north of England and in Scotland, where stone is plentiful. Walls faced with ashlar, and backed with brick or uncoursed rubble, are liable to become convex on the outside from the greater number of joints, and from the greater quantity of mortar placed in each joint, as the shrinking of the mortar will be in proportion to the quantity; and therefore a wall of this description is much inferior to one of which the facing and backing are of the same kind, and built with equal care, even though both sides were uncoursed rubble, which is the worst of all walling. Where the outside of a wall is an ashlar facing, and the inside coursed rubble, the courses of the backing should be as high as possible, and set with thin beds of mortar. In Scotland, where stone abounds, and where perhaps as good ashlar facings are constructed as any in Great Britain, the backing of their walls most commonly consists of uncoursed rubble, built with very little care. In the north of England, where the ashlar facings of walls are done with less neatness, they are much more particular in the coursing of their backings. Coursed rubble and brick backings are favourable for the insertion of bond timbers: but in good masonry, wooden bonds should never be in continued lengths, as in case of fire or rot, the wood will perish, and the masonry, being reduced by the breadth of the timber, will be liable to bend at the place where it is inserted. When it is necessary to have wall timber for the fastening of battens for lath and plaster, the pieces of timber ought to be built with the fibres of the wood perpendicular to the surface of the wall, or otherwise in unconnected short pieces, not exceeding nine inches in length.

In an ashlar facing, the stones generally run from twenty-eight to thirty inches in length, twelve inches in height, and

eight or nine inches in thickness. Although both the upper and lower beds of an ashlar, as well as the vertical joints, should be at right angles to the face of the stone, and the face-bed and vertical joints at right angles to the beds in an ashlar facing, where the stones run nearly of the same thickness, it is of some advantage, in respect of bond, that the back of the stone be inclined to the face, and that all the backs thus inclined should run in the same direction, as this gives a small degree of lap in the setting of the next course; whereas, if the backs were parallel to the front, there could be no lap where the stones run of an equal depth in the thickness of the wall. It is of some advantage likewise to select the stones, so that a thicker one and a thinner one may follow each other alternately. The disposition of the stone in the next superior course should follow the same order as in the inferior course, and every vertical joint should fall as nearly as possible in the middle of the stone below.

In every course of ashlar facing, with brick or rubble backing, *thorough-stones*, (as they are technically termed,) should be introduced, and their number should be proportioned to the length of the course, and every such stone of a superior course should fall in the middle of every two similar stones in the course below; this disposition of bonds should be strictly attended to in all long courses. Some wallers, in order to show or demonstrate that they have introduced sufficient bonds in their work, choose their bond-stones of greater length than the thickness of the wall, and knock or cut off their ends afterwards. This method is far from being eligible, as the wall is not only liable to be shaken by the force applied to break the end of the stone, but the stone itself is apt to be split.

In every pier where the jambs are coursed with the ashlar in front, every alternate jamb-stone ought to go through the wall, with its beds perfectly level. If the jamb-stones are of one entire height, as is frequently the case when architraves are wrought upon them, and upon the lintel crowning them, in the stones at the ends of the courses of the pier which are to adjoin the architrave jamb, every alternate stone ought to be a thorough-stone; and if the piers between the apertures be very narrow, no other bond-stones will be necessary in such short courses. But where the piers are wide, the number of bond-stones must be proportioned to the space; thorough-stones must be particularly attended to in the long courses below and above windows.

Bond-stones should have their sides parallel, and of course be perpendicular to each other, and their horizontal dimension in the face of the work should never be less than the vertical one. All the vertical joints, after receding about three quarters of an inch from the face with a close joint, should widen gradually to the back, and thereby form hollow wedge-like figures for the reception of mortar and packing. The adjoining stones should have their beds and vertical joints filled with oil putty from the face to about three-quarters of an inch inwards, and the remaining part of the beds with well-prepared mortar. Putty cement will stand longer than most stones, and will even remain prominent when the stone itself is in a state of dilapidation from the influence of the corroding power of the atmosphere. It is true that in all newly-built walls cemented with oil putty, the first appearance of the ashlar work is rather unsightly, owing to the oil of the putty disseminating itself into the adjoining stones, which makes the joints appear dirty and irregular: but this disagreeable effect is soon removed; and if care has been taken to make the colour of the putty suitable to that of the stone, the joints will hardly appear, and the whole work will seem as if one piece. This is the practice in Glasgow, but in London and in Edinburgh fine water putty is used instead of it.

All the stones of an ashlar facing should be laid on their natural beds. From a neglect of this precaution, the stones frequently flush at the joints, and this disposition of the laminæ sooner admits the corrosive power of the atmosphere to take effect.

In building walls or insulated pillars of very small horizontal dimensions, every stone should have its bed level, and without any concavity in the middle; because if the beds are concave, when the pillars begin to sustain the weight of the fabric, the joints will in all probability flush. It ought likewise to be observed, that every course of masonry of such piers ought to consist of one stone.

An arch, in masonry, is a part of a building suspended over a given plan, supported only at the extremities, and concave towards the plan.

The supports of an arch are called the *spring walls*.

The whole of the under surface of the arch opposite to the plan is called the *intrados* of the arch; and the upper surface is called the *extrados*.

The boundary line or lines of the intrados or those common to the supports and the intrados, are called the *springing lines* of the arch.

A line extending from any point in the springing line on one side of the arch, to the springing line on the opposite side of the arch, is called the *chord* or *span* of the arch.

If a vertical plane be supposed to be contained by the span and the intrados of the arch, it is called the *section of the hollow* of the arch.

The vetrical line drawn on the section from the middle of the spanning line to the intrados, is called the *height* of the arch, as also the *middle line* of the arch; and the part of the arch at the upper extremity of this line is called the *crown* of the arch.

Each of the curved parts on the top of the section, between the crown and either extremity of the spanning line, is called the *haunches* or *flanks* of the arch.

The section of almost every given arch used in building has the following properties: the upper part is one continued curve, concave towards the span, or two curves forming an interior angle at the crown, both concave towards the spanning line. Every two vertical lines on the section equidistant from each extremity, and parallel to the middle line, are equal.

The foregoing definitions and propositions not only apply to arches with level bases, but also to arches which stand upon inclined bases.

When the base of the section or spanning line is parallel to the horizon, the section will consist of two equal and similar parts, so that if one were conceived to be folded upon the other, the boundaries of both would coincide.

Arches, whose intrados is the surface of a geometrical solid that would fill the void, are variously named, according to the figure of the section of that solid perpendicular to the axis, as *circular*, *elliptical*, *cycloidal*, *catenarian*, *parabolical*, &c.

Arches of the circular kind have two distinctions, viz., the *semicircular*, and those of segments less than a semicircle; the latter are called *scheme* or *skene* arches.

There are also *pointed*, *composite*, *lancet*, or *Gothic* arches, which are formed in the face of the wall, or in sections parallel thereto, with the intrados of the arch.

When the extremities of an arch rise from supports at unequal heights, it is called a *rampant* arch.

When vertical lines are drawn upwards, through each extremity of the spanning line, so as to cut off equal and

similar parts of the intrados, the arch is called a *horse-shoe* arch, or *moresque* arch. Hence, in this kind of arch, the spanning line is less than any other line or chord drawn parallel to the span, but under the top of each of the vertical lines.

When the upper line or side of an arch is parallel to the under line or side, it is called an *extradossed* arch.

A simple vault is an interior concavity extended over two parallel opposite walls, or over all the diametrically opposite parts of one circular wall. An arch or vault is frequently understood as synonymous; but the distinction which we shall here observe is, that an arch, though it may be extended over any space, has a very narrow intrados, not exceeding four or five feet; whereas a vault may be extended to any limit more than four or five feet. Thus we frequently say an arch in a wall, but we never say a vault in a wall; though nothing is more common than to say a vaulted apartment, a vaulted room, a vaulted cellar, &c. So that a vault, as Sir Henry Wotton has observed, is an extended arch; we shall therefore apply *arch* to the head of the aperture in a wall which shows curvilinear intersections with the faces of the wall, and the word *vault* to arched apartments. We frequently, however, call the stone-work suspended over an apartment an arch as well as a vault; so that every vault is an arch, but every arch is not a vault.

The intrados of a simple vault is generally formed of the portion of a cylinder, cylindroid, sphere, or spheroid, never greater than the half of the solid; and the springing lines which terminate the walls, or where the vault begins to rise, are generally straight lines parallel to the axis of the cylinder, or cylindroid, or the circumference of a circle or ellipsis.

A circular wall is generally terminated with a spherical vault, which is either hemispherical, or a portion of a sphere less than a hemisphere.

A vaulted apartment, surrounded by an elliptic wall, is generally covered with a spheroidal vault, which is either a hemispheroid, or a portion less than a hemispheroid.

A conic surface is seldom employed in vaulting; but when the vault is to have this kind of intrados, the intrados should be the half of a cone with its axis in a horizontal position, or a whole cone with its axis in a vertical position.

All vaults which have a horizontal straight axis, are called *straight vaults.*

Besides what we have already denominated an arch, the concavities which two solids form at an angle, are called *an arch.*

If one cylinder pierce another of a greater diameter, the arch is called a *cylindro-cylindric arch;* the cylindro being applied to the cylindric part which has the greater diameter, and the cylindric to that which has the less.

If a cylinder pierce a sphere of greater diameter than the cylinder, the arch is called *a sphero-cylindric arch;* and, on the contrary, if a sphere pierce a cylinder of greater diameter than the sphere, the arch is denominated *a cylindro-spheric arch.*

If a cylinder pierce a cone, so as to make a complete perforation through the cone, two complete arches will be formed, called *cono-cylindric arches;* and, on the contrary, if a cone pierce a cylinder, so as to make the interior concavity through the cylinder a complete conic surface, the arch is called *a cylindro-conic arch.*

If a straight wall be pierced with a cylindric aperture quite through, two arches will be formed, called *plano-cylindric arches.*

Every species of arches is thus denoted by two preceding words; tne former ending in *o*, signifying the principal vault or surface cut through, and the latter in *ic*, signifying the kind of aperture which pierces the wall or vault.

When two cylindric vaults, or two cylindroidic vaults, or a cylindric or cylindroidic vault, pierce each other, and also their axis, so that the diameter of each hollow may be the same, when measured perpendicular to a plane passing through the axis of both surfaces, the figure so formed is called a *groin;* but for more particular information on this point see the article GROIN.

The formation of stone arches, in various cases, has always been looked upon as a most curious and useful acquisition to the operative mason, or to the architect, or other person who is appointed to superintend the work. In order to remove the difficulties experienced in the construction of cylindric or cylindroidic arches, both in straight and circular walls, we shall here show an example of each.

First, let it be required to construct a semi-cylindroidic arch, cutting a straight wall with its axis oblique to the surface of the wall, but parallel to the horizon.

Plate I. Figure A.—Let A B C D be the plan of the aperture, A D and B C being the plan of the jambs, and A B and D C the plan of the sides of the wall; produce D A and C B to G and F; draw the straight line I G M F E at right angles with A G and C F; bisect G F at M; draw M H K perpendicular to C F; make M H equal to the height of the intrados of the arch, and describe the semi-ellipsis G H F, which is the section of the intrados of the arch; make G I, H K, and F E, equal to the breadth of the beds of the arch-stone, and describe the semi-ellipsis I K E, which is the section of the extrados of the arch. Now, suppose the distances between the joints around the intrados of the arch to be all equal, and all the joints to tend to the centre M; divide the semi-ellipsis into such an odd number of equal parts, that each part may be in breadth equal to what is intended for the thickness of the stones at that part; produce E I to S, and extend the whole number of these parts from G to S; and through the points of division draw lines perpendicular to G S, or parallel to A G. Through all the points of division of the ellipsis G H F, draw lines parallel to G A to meet A B; then take the lengths of all the parts of the lines so drawn that are terminated by G F and A B, as follows, viz., make the first line on the left of G A equal to the first on the right of G A, and the point *b* will be obtained; make the second on the left of G A equal to the second on the right of G A, and the point *c* will be obtained; proceed in this manner, until all the other points are obtained; then a curve being drawn through all the points A, *b*, *c*, *d*, &c. to T, will give the one edge of the envelope of the intrados of the arch; and by producing the perpendiculars erected upon G S to the points *e*, *f*, *g*, &c., and making the several distances *b e*, *c f*, *d g*, &c. equal to A D or B C, the points D, *e*, *f*, *g*, &c. to U, will give the other edge of the envelope by tracing a curve through them; then A *b c d*, *b c f e*, *c d g f*, &c. are the soffits of the stones.

To find any bevel which the joints on the face of the arch makes with that on the intrados.

Let *p q* be one of the joints tending to the centre, M, of the section of the arch; with the radius M G describe an arc, G N O, cutting *p q* at N; draw N P parallel to G A, cutting A B at P; draw P Q parallel to F G, cutting G A at Q; draw M L parallel to G A, cutting A B at L, and join L O; then Q L M is the bevel required. In the same manner may all the remaining bevels be found.

Again, let *p q r s* be the section of an arch-stone; then making two bevels, one to *q p s*, and the other to *r s p*, will be all the bevels that are necessary for that stone. Having obtained the several bevels, we shall now proceed to work the arch-stone, whose section is *p q r s:* first work the lower bed of the stone corresponding to the joint *p q*, then draw a

line for the soffit, which work also by means of the bevel *q p s;* then gauge the soffit to its breadth, and work the upper bed of the stone by means of the bevel *r s p;* take the soffit mould from the envelope, and draw the ends of the stone which coincide with the faces of the wall; with the face bevels Q L M and V L M work the face of the stone.

Note.—That finding the bevels for half the arch will be sufficient, by reversing them.

Plate II. shows the construction of a semi-cylindric arch, which is performed by a similar process to the preceding.

The other arch, standing upon D C, shows the ends of the stones in the face of the wall; its boundaries are two ellipses of equal height to those of the section.

To construct a cylindro-cylindric arch, or a cylindric arch, in a cylindric wall, the axis of the aperture being at right angles to the axis of the cylindric wall. *See* PLATE III.

Let A B C D be the half plan of the wall; B C being half of the convex curve, A D half of the concave curve, C D the middle line of the aperture tending to the centre of the concentric circles which form the plan; and A B parallel to C D, being the jamb. Through C draw E F perpendicular to C D; make C E and C F half the breadth of the aperture; from the centre, C, with the radius C E or C F, describe the semicircle E G F, which will be the section of the intrados; produce C E and C F to H and I, making E H and F I each equal to the breadth of the beds, and describe the semicircle H K I; divide the intradossal curve, E G F, into the number of parts answering to the number of arch-stones, and proceed to find the envelope, as described, for the straight wall, which will give the moulds for the soffits of the stones, as before.

To find the curves of the ends of the beds upon the face of the arch.

Let L M represent a joint: draw L N and M O perpendicular to H I, cutting the plan of the wall at N and O: draw N P parallel to C I, cutting M O at P: in L M take any number of points, *t* and *y*, and draw *t s* and *y w* parallel to L N, cutting the plan at *s* and *w*, and N P at *r* and *v*: draw M Q, *t u*, *y x*, perpendicular to L M: make M Q, *t u*, *y x*, respectively equal to P O, *r s*, *v w*, and L *x u* Q will be the curve of the joint required, which gives the face-line of the upper bed of the lower stone, and the face-line of the lower bed of the upper stone. In the same manner all the other face-lines of the beds are to be found. The templet must be cut in the shape of L M Q.

To form an arch-stone.

First make one of the beds; make the soffit, form the other bed, and the face-lines of each bed; then run a draught round the three face-lines, and between them work the face of the stone in lines perpendicular to the horizon. This will be easily found by drawing a vertical line upon the section of each stone.

It is only necessary to draw the moulds for one half of the arch, as the reversing of them in their application gives the other half.

The joints of any arch whatever may be found in the same manner, provided the planes of the beds intersect a vertical plane perpendicular to the curve in the middle of the aperture.

It is obvious, on finding the face-lines of the beds, that the lowest face-line is the quickest, and part of the plan of the wall itself; the next face-line is flatter, or has less curvature, and thus each successive face-line has less curvature as it comes nearer to the top; and, if there were a joint in the top, the face-line of the beds would be quite a straight line. Indeed, the face-lines of two or three courses might be wrought with straight edges, as the difference could hardly be perceived. For the tools used by masons. *See* TOOLS.

MATERIALS, (from the French, *materiel,*) in architecture, the different kinds of bodies, or substances, used in the construction of edifices, as wood, stone, brick, mortar, &c.

It is chiefly from the valuable work of Vitruvius, that we are furnished with information respecting the nature of the materials used by the Greeks and Romans, and of the particular modes in which they were disposed in their buildings. From the accounts published by modern travellers and scientific artists, we are also furnished with farther information respecting the practice of these people.

The materials chiefly made use of by them were timber, marble, stone, bricks, lime, and metals.

With regard to timber, the proper time for felling was reckoned from the beginning of autumn to the latter end of February, when the moon was in the wane. They considered wood, when quite green, or too much dried, as equally unfit for working. For joists, doors, and windows, they required that it should have been cut three years, and kept for a considerable time covered with cow-dung.

The Greeks most usually made use of white marbles as Pentelic, Parian, and that of Chios. The latter was very transparent.

The Romans employed many sorts, of various colours, and procured from different countries under their sway in Asia, Africa, and Europe.

The ancients frequently included, under the term *marble,* all hard stones which would receive a smooth fine polish; the moderns confine the name to such calcareous stones as are capable of receiving a fine polish.

Alabaster resembles marble in taking a smooth fine polish, but is much softer and more easily worked. Gypseous alabaster, when polished, is slippery to the touch; and frequently contains so much carbonate of lime as to cause it to effervesce with acids; it was procured from Upper Egypt between the Nile and Red Sea, also from Syria and Caramania. The calcareous alabaster is white, yellow, red, and bluish gray; the fracture is striated or fibrous, in hardness inferior to marble; it is known under the denomination of *common* and *oriental;* Italy and Spain produce the best.

The stone which was employed appears to have differed very materially in its qualities; some, becoming considerably harder on being exposed to the air, was worked immediately on being taken from the quarry; but there was some of a softer kind, which, previous to being used, required to have its quality proved by two years' exposure to the effects of the atmosphere.

Of tiles, they had, 1. The unburnt kind, which were dried five years in the sun; and, 2. Those baked by fire, after having been made two years.

In the manufacture of these, they preferred a white chalky earth, dug in the autumn, exposed during the winter, and made into tiles and bricks in the spring. The Greeks proportioned the size of their bricks to the nature of the edifice: the largest for public buildings, were five spans each way; those of the middle class were four spans; and the smallest called by Vitruvius, *diodori*, or by Pliny, *lydii*, were two spans long and a foot broad; the last were for private houses.

It appears that the bricks dried in the sun were mixed with chopped straw. Dr. Pococke describes one of the pyramids constructed of brick: he measured some thirteen inches and a half long, six inches and a half broad, and four inches thick; others were fifteen inches long, seven inches broad, and four inches and three-quarters thick. At Rome they were found by De Quincey of three different sizes; the least were seven inches and a half square, and one inch and a half thick; the middle-sized were sixteen inches and a half square,

and eighteen to twenty lines in thickness; and the largest were twenty-two inches square, and twenty-one to twenty-two lines in thickness.

Three kinds of sand are mentioned, that is, pit, river, and sea sand; of these, pit sand was reckoned the best; the white was preferred to the black or red coloured, and the carbuncle to all; of the river sand, that was considered best which was found near torrents; the least value was put upon sea sand, and it was required to be well washed, to dissolve the saline matter, before it was used in plastering or rough-casting walls.

Lime for plastering walls was made from shells, river pebbles, or a sort of pumice-stone; the best sort of lime was accounted that made from white stone, which was dense and hard, and lost one-third of its weight in burning in a kiln, where it was kept about sixty hours. Their mortar was composed of one part lime and three parts of pit, or two of river sand.

Metals used were, 1. Iron for chains, hinges, handles, and nails. 2. Lead for roofs and pipes. 3. Copper and brass were still more used for many of these purposes: or, 4. Copper, brass, and lead, mixed into a bronze for statues, bases, and capitals of columns, and in doors.

Amongst the moderns, change of climate, the convenience of local productions, and the habits of mankind, have from time to time led to considerable changes in the kinds of materials used for the various purposes of architecture, as well as in their modes of preparation, and the application of them. With regard to timber, oak, for the greatest strength and durability, should be chosen from those soils where it has taken the longest time in arriving at maturity; and of two pieces equally dry, that should be chosen which has the greatest specific gravity, or that which will have its specific gravity least changed by being soaked in water: this observation will indeed apply to timber in general. A decay of the top is almost a certain indication of a decay of the tree; and a decayed branch, or rotten stump, bespeaks a defect in that part of the tree where it is situated. In a similar soil, trees which grow near the outside of a forest will be more durable than those near the middle of it; and in the same tree, the side which grew towards the north will be stronger than the south side.

When perfection of strength and texture is alone consulted, all sorts of timber are cut down in the winter, being at that time freest of sap, and most readily seasoned, and rendered fit for the purposes of building; but on account of the bark of the oak being of great use in tanning leather, that wood is always, in England, cut in the spring, from April to June, according to the state of the season, and soon after the sap begins to ascend and the leaf to appear; if cut before the sap rises, the bark adheres to the wood, and cannot be stripped off, and if left until the leaf is quite expanded, the bark is less valuable; when the tree is felled and suffered to lie in the trunk, it will shrink in size; but this is probably from its discharging water, because, if a dry tree be laid in a damp place, it will increase both in weight and size. The part called *sap* varies in quantity in different trees; it is least in bad soils, where the growth is slow, and is of very little use.

Oak used in damp situations, appears to decay gradually from the external surface to the centre of the tree; the outside ring or addition it received in the last year of its growth decaying first, and afterwards that next within it, and then the following one. This appears to proceed from two causes; first, from the outward ring being, where whole trees are used, first exposed to the action of the atmosphere, which cannot reach the second until the first is destroyed; secondly, from the central part of the tree having arrived at a greater degree of maturity than the outward rings, which are many years younger. But this must be understood only of trees which are not past their prime before they are cut down; for when a tree begins to decay from age, that part of the tree which is oldest, namely, the central part, decays first; to this succeeds the parts which are next oldest, being the ring next the centre, and the other annual rings in succession gradually approaching the bark. A judicious builder will, therefore, in the choice of his timber, always carefully examine the central part of the tree, especially that part which is next the root, and more particularly if the tree be large, and have the appearance of great age.

The best mode of seasoning oak is to put it in water. This, if in the log, should be done for a whole year or more, but, if cut in planks, less time is necessary; in either case alternate soaking and drying is to be preferred. This, in planks, is very practicable; but, in regard to logs, one soaking and drying gradually in the shade, is, on account of the great labour attending the operation, most generally practised. After the planks have been soaked in water, they are dried by placing a strong pole in a horizontal position, at such a height as will admit of one end of each plank being placed on the ground, and the other to rest against it edgewise; placing a plank first on one side of the pole, and another on the other side alternately, thus leaving a space for the air to pass freely between them; and being exposed edgewise to the sun, they are not liable to split.

Modern science, however, has discovered many other ways of seasoning timber than these. The processes of Sir W. Burnett, Kyan, and others, are now generally resorted to for this purpose; and are found effective to a certain extent, if not quite realizing all their advocates claim for them.

In ash, there is little difference in the quality through the whole thickness of the tree, the outside is rather the toughest: it soon rots when exposed to the weather, but will last long when protected.

Of elm, some sorts will decay sooner than the brown or red. It is improper for roofs or floors, being generally cross-grained, and very liable to warp; it also shrinks very considerably, not only in breadth, but lengthwise; but it answers well when used under water; is not liable to split; and bears the driving of bolts and nails better than any other timber.

Beech is hard and close. There is a black or brown, and a white kind: the brown is tough, and sometimes used as a substitute for ash; it is improper for beams, because a small degree of dampness in the walls very soon rots the ends; it is most suitable for furniture, or for works constantly under water.

Poplar, though of a very close quality, is liable to the same objections as the beech in beams, but is well adapted for floors and stairs, being not easily ignited: however, it rots soon when exposed to the weather.

Ash resembles the poplar in appearance; is soft and tough; lasts when exposed to the weather; and is equally good through the body of the tree. The sycamore and lime are subject to the same objections, in roofing and flooring timbers, as the poplar and beech. The lime is something like the ash in quality, and, like it, is greasy when worked smooth: it is suitable for furniture.

Birch is equal in quality quite across the body of the tree; is very tough, but does not last when exposed to the weather; it is also subject to be destroyed by worms.

Chesnut, viz., the sweet, or Spanish, (not the horse-chesnut,) is frequently found in old buildings in England: and although difficult to be distinguished from oak, differs from

it in this respect, wherever a nail or bolt has been driven into oak before it was dry, a black substance appears round the iron, which is not the case in chesnut.

The walnut-tree is now, in this country, too valuable to be used in the framings of roofs or floors; and in furniture it has long been superseded by mahogany; it is used chiefly in stocks of firelocks, fowling-pieces, pistols, &c.

Mahogany is used chiefly in furniture, and also sometimes in doors and window-sashes; it is sawn out and seasoned by perching out in the winter, and drying in the open air; the use of fire is not advisable. This beautiful timber was introduced into England about the beginning of the last century: its first application was in a box for holding candles, made by a Mr. Wollaston for a Dr. Gibbons, who had afterwards a bureau of it; the Duchess of Buckingham had the second bureau. It very soon came into general use. It is divided chiefly into Jamaica and Honduras; the former is by much the hardest and most beautiful; they may be readily distinguished before they are oiled; the pores of the Honduras appear quite dark, those of the Jamaica as if filled with chalk. *See* MAHOGANY.

Fir, being cheaper, and more easily wrought than oak, and next to it in usefulness, is more used in Britain than any other kind of timber. That most generally employed in carpentry is distinguished by the name of Memel, (which includes Dantzic and Riga;) Norway, (which also includes Swedish,) is much used for the smaller timbers, and answers well either when exposed to the air, or under ground. Dranton, or Dram, is suitable for flooring. All these are very durable. American fir is much softer, but suits inside joinery work, such as panels and mouldings. What is termed in England *white deal*, and in Scotland *pine-wood*, that is, fir deprived of its resinous part, being very durable when kept dry, is much used by cabinet-makers; but, as it will not stand the weather, it is little used in carpentry or joinery.

Evelyn makes the following observation on the use of fir:—"That which comes from Bergen, Swinsund, Mott, Longland, Dranton, (called Dram,) being long, straight, and clear, of a yellow and more cedary colour, is esteemed much before the white for flooring and wainscot; for masts, those of Prussia, which we call spruce, and Norway, especially from Gottenburg, and about Riga, are the best."

The *torulus*, as Vitruvius terms it, and heart of deal, kept dry, rejecting the alburnum or white, is everlasting; nor is there any wood which so well agrees with the glue, or which is so easy to be wrought. It is also excellent for beams, and other timber-work in houses, being both high and exceedingly strong, and therefore of very great use for bars and bolts of doors, as well as for doors themselves; and, for the beams of coaches, a board of an inch and a half thick will carry the body of a heavy coach with great ease, by reason of a natural spring, which is not easily injured. It was formerly used for carts and other carriages, and also for the piles to build upon in boggy grounds. Most of Venice and Amsterdam is built upon such piles. For scaffolding also, there is none comparable to it. Under the head of fir may be classed cedar, a wood of great durability, but too expensive to be used in Britain.

Evelyn makes the following observations upon timber; some of which are well worthy of attention:—

"Lay up your timber very dry, in an airy place, yet out of the wind or sun, and not standing upright, but lying along, one piece upon another, interposing some short blocks between them, to preserve them from a certain mouldiness which they usually contract while they sweat, and which frequently produces a kind of fungus, especially if there be any sappy parts remaining

"Some there are yet, who keep their timber as moist as they can by submerging it in water, where they let it imbibe to hinder the cleaving; and this is good in fir, both for the better stripping and seasoning, yea, and not only in fir, but other timber. Lay, therefore, your boards a fortnight in the water, (if running the better, as at some mill-pond head,) and then setting them upright in the sun and wind, so as it may freely pass through them, (especially during the heats of summer, which is the time of finishing buildings,) turn them daily, and thus treated, even newly-sawn boards will floor far better than many years' dry-seasoning, as they call it. But, to prevent all possible accidents, when you lay your floors, let the joints be shot, fitted, and tacked down only for the first year, nailing them for good and all the next; and by this means they will lie stanch, close, and without shrinking in the least, as if they were all one piece. And upon this occasion, I am to add an observation, which may prove of no small use to builders; that if one take up deal-boards that may have lain in the floor a hundred years, and shoot them again, they will certainly shrink, (*toties quoties*,) without the former method. Amongst wheelwrights, the water-seasoning is of especial regard; and in such esteem amongst some, that I am assured the Venetians, for their provision in the arsenal, lay their oak some years in water before they employ it. Indeed, the Turks not only fell at all times of the year, without any regard to the season, but employ their timber green and unseasoned; so that, though they have excellent oak, it decays in a short time by this only neglect.

"Elm felled ever so green, for sudden use, if plunged four or five days in water, (especially salt water,)obtains an admirable seasoning, and may immediately be used. I the oftener insist on this water-seasoning, not only as a remedy against the worm, but for its efficacy against warping and distortions of timber, whether used within or exposed to the air. Some, again, commend burying in the earth, others in wheat; and there be seasonings of the fire, as for the scorching and hardening of piles, which are to stand either in the water or in the earth.

"When wood is charred, it becomes incorruptible; for which reason, when we wish to preserve piles from decay, they should be charred on their outside. Oak posts, used in enclosures, always decay about two inches above and below the surface. Charring that part would probably add several years to the duration of the wood, for that to most timber it contributes much to its duration. Thus, do all the elements contribute to the art of seasoning.

"And yet even the greenest timber is sometimes desirable for such as carve and turn, but it chokes the teeth of our saws; and for doors, windows, floors, and other close works, it is altogether to be rejected, especially where walnut-tree is the material, which will be sure to shrink. Therefore, it is best to choose such as is of two or three years' seasoning, and that is neither moist nor over dry; the mean is best. Sir Hugh Plat informs us, that the Venetians used to burn and scorch their timber in a flaming fire, continually turning it round with an engine, till they have gotten upon it a hard black coaly crust; and the secret carries with it great probability, for the wood is brought by it to such a hardness and dryness, that neither earth nor water can penetrate it; I myself remembering to have seen charcoal dug out of the ground amongst the ruins of ancient buildings, which had in all probability lain covered with earth above fifteen hundred years.

"Timber which is cleft is nothing so obnoxious to reft and cleave, as what is hewn; nor that which is squared, as what is round; and therefore, where use is to be made of huge and

massy columns, let them be bored through from end to end. It is an excellent preservative from splitting, and not unphilosophical; though, to cure the accident, painter's putty is recommended; also, the rubbing them over with a wax-cloth is good; or before it be converted, the smearing the timber over with cow-dung, which prevents the effects both of sun and air upon it, if, of necessity, it must lie exposed. But, besides the former remedies, I find this for the closing of the chops and clefts of green timber, to anoint and supple it with the fat of powdered beef-broth, with which it must be well soaked, and the chasms filled with sponges dipt into it. This to be twice done over.

"Some carpenters make use of grease and sawdust mingled; but the first is so good alway," says my author, "that I have seen wind-shock timber so exquisitely closed, as not to be discerned where the defects were. This must be used when the timber is green.

"We spake before of squaring; and I would now recommend the quartering of such trees as will allow useful and competent scantlings, to be of much more durableness and effect for strength, than where (as custom is, and for want of observation) whole beams and timbers are applied in ships or houses, with slab and all about them, upon false suppositions of strength beyond these quarters. For there is in all trees an evident interstice or separation between the heart and the rest of the body, which renders it much more obnoxious to decay and miscarry, than when they are treated and converted as I have described it; and it would likewise save a world of materials in the building of great ships, where so much excellent timber is hewed away to spoil, were it more in practice. Finally,

"I must not omit to take notice of the coating of timber in work used by the Hollanders, for the preservation of their gates, portcullises, draw-bridges, sluices, and other huge beams and contiguations of timber, exposed to the sun and perpetual injuries of the weather, by a certain mixture of pitch and tar, upon which they strew small pieces of cockle and other shells, beaten almost to powder, and mingled with sea-sand, or the scales of iron, beaten small and sifted, which encrusts, and arms it, after an incredible manner, against all these assaults and foreign invaders; but if this should be deemed more obnoxious to firing, I have heard that a wash made of alum has wonderfully protected it against the assault even of that devouring element; and that so a wooden tower or fort at the Piræum, the port of Athens, was defended by Archelaus, a commander of Mithridates, against the great Sylla.

"Timber that you have occasion to lay in mortar, or which is in any part contiguous to lime, as doors, window-cases, groundsels, and the extremities of beams, &c., have sometimes been capped with molten pitch, as a marvellous preserver of it from the burning and destructive effects of the lime; but it has since been found rather to heat and decay them, by hindering the transudation which those parts require: better supplied with loam, or strewings of brick-dust, or pieces of boards; some leave a small hole for the air. But though lime be so destructive whilst timber lies thus dry, it seems they mingle it with hair, to keep the worm out of ships, which they sheath for southern voyages, though it is held much to retard their course. Wherefore, the Portuguese scorch them with fire, which often proves very dangerous; and, indeed, their timber being harder, is not so easily penetrable.

"For all uses, that timber is esteemed the best which is the most ponderous, and which, lying long, makes deepest impression on the earth, or in the water, being floated; also, what is without knots, yet firm, and free from sap, which is that fatty, whiter, and softer part, called by the ancients *alburnum*, which you are diligently to hew away.

"My Lord Bacon, Exper. 658, recommends for trial of a sound or knotty piece of timber, to cause one to speak at one of the extremes, to his companion listening at the other; for if it be knotty, the sound, says he, will come abrupt.

"For the place of growth, that timber is esteemed best which grows most in the sun, and on a dry and hale ground; for those trees which suck and drink little, are most hard, robust, and longer-lived instances of sobriety. The climate contributes much to its quality; and the northern situation is preferred to the rest of the quarters; so as that which grew in Tuscany was, of old, thought better than that of the Venetian side; and yet the Biscay timber is esteemed better than what they have from colder countries; and trees of the wilder kind and barren, than the over-much cultivated and great bearers."

Dr. Parry published an excellent paper on the causes of the decay of wood, and the means of preventing it, which, though written many years ago, is worth a careful perusal by those who wish for further information on the subject.

Wood, Dr. Parry supposes to be subject to destruction from two causes—rotting, and the depredations of insects. Of rot there are two supposed kinds: the first takes place in the open air; the second under cover.

When perfectly dry, and in a certain degree of temperature, both animal and vegetable matters seem scarcely capable of spontaneous decay. On this principle, fish and other animal matter is often preserved.

"Similar causes produce the same effect on wood. Even under less rigid circumstances of this kind, as in the roofs and other timber of large buildings, it continues for an astonishing length of time unchanged. Witness the timber of that noble edifice, Westminster-hall, built by Richard II. in 1397; and the more extraordinary instance quoted by Dr. Darwin, in his ingenious work, the *Phytologia*, of the gates of the old St. Peter's Church in Rome, which were said to have continued without rotting, from the time of the Emperor Constantine to that of Pope Eugene IV., a period of eleven hundred years. On the other hand, wood will remain for ages, with little change, when continually immersed in water, or even when deeply buried in the earth, as in the piles and buttresses of bridges, and in various morasses. These latter facts seem to show, that if the access of atmospherical air is not necessary to the decay of wood, it is at least highly conducive to it."

Putrefaction is the cause of rotting; and putrefaction is occasioned by stagnant air and moisture. The moisture of the air, coming in contact with wood of a lower temperature, is condensed in the same manner, as is more visible in our glass windows. In order to prevent the bad effects of this condensation, currents of dry air ought to be made to pass in contact with the timber. Of the advantages of this, the Gothic architects seemed aware; for it was common with them to leave openings for this purpose; a practice which we would strongly recommend in cellars, &c.

"It appears that the contact of water and air are the chief causes of the decay of wood. If, therefore, any means can be devised by which the access of moisture and air can be prevented, the wood is so far secure against decay. This principle may be illustrated, by supposing a cylinder of dry wood to be placed in a glass tube or case which it exactly fills, and the two ends of which are, as it is called, hermetically sealed, that is, entirely closed, by uniting the melted sides of each end of the tube. Who will doubt that such a piece of wood might remain in the open air unchanged! Or let us take a little more apposite illustration of this fact, that

of amber, a native bitumen or resin, in which a variety of small flies, filaments of vegetables, and others of the most fragile substances, are seen imbedded, having been preserved from decay much longer probably than a thousand years, and with no apparent tendency to change for ten times that period."

These observations lead to the theory of painting timber, for the purpose of preserving it.

Mr. Batson of Limehouse is of opinion, that the dry-rot proceeds from a plant, called *boletus lachrymans*, one of the fungus tribe, and is one of the few that have leaves, as the mistletoe. But Dr. Parry justly observes, that these plants "begin merely because decayed wood is their proper soil."

"The smell which we perceive in going into vaults or cellars, where this process is going on, arises partly from the extrication of certain gases, mingled perhaps with some volatile oil, and partly from the effluvia of those vegetable substances which have already been said to grow on it, and which, though they begin merely because the decayed wood is their proper soil, yet afterwards tend probably to the more speedy decomposition of the wood itself.

"The following, then, appears to be the whole theory of the dry-rot, that it is a more or less rapid decomposition of the substance of the wood, from moisture deposited on it by condensation, to the action of which it is more disposed in certain situations than in others; and that this moisture operates most quickly on wood which most abounds with the saccharine or fermentable principles of the sap." *See* DRY-ROT.

Charring of wood is known to be a most effectual mode of preservation against rotting.

The incorruptibility of charcoal is attested by numerous unquestionable facts. At the destruction of the famous temple at Ephesus, it was found to be erected on piles that had been charred; and the charcoal in Herculaneum, after almost 2,000 years, was entire and undiminished.

To this property of charred wood Sir C. Wren does not seem to have attended, when about to build St. Paul's. It is said, he thought piles were not to be depended on for a foundation, excepting when always wet; and therefore dug to a great depth through a dry soil, in order to come at a solid foundation for part of that cathedral.

Charcoal has also been found useful as a defence to the surface of wood, when used as a paint. We lately had a good instance of the effect of sand used for this purpose. At Studly Royal, we saw a temple to appearance of stone, but which, on examination, we found to be wood covered with paint and dusted over with sand. We were informed it had stood about 50 years; and the deception was still so complete, that the spectators supposed the pillars to be stone, till minutely examined.

The following table of the properties of different kinds of timber is extracted from Tredgold's valuable work on Carpentry, and will be found to contain, in a condensed form, every information as to the comparative merits of the various descriptions of wood used for building or similar purposes:—

Table of the Properties of different kinds of Timber.

		Kind of wood, and State.	Specific gravity.	Weight of the modulus of elasticity in pounds per sq. inch.	Cohesive force in pounds per sq. inch.	Comparative.		
						Stiffness.	Strength.	Resilience.
Class I.	Div. I.	Common oak (*Quercus robur*) dry	.750	1,714,500	11,880	100	100	100
		Riga oak, dry	.688	1,610,496	12,888	93	108	125
		Dantzic oak, seasoned	.755	1,998,000	12,780	117	107	99
		American oak	.867	1,958,700	10,253	114	86	64
	Div. II.	Beech (*Faguz Sylvatica*) dry	.690	1,316,000	12,225	77	103	138
		Alder (*Betula alnus*) dry	.555	1,086,750	9,540	63	80	101
		Plane (*Platanus occidentalis*) dry	.648	1,343,250	10,935	78	92	108
		Sycamore (*Acer pseudo-platanus*) dry	.590	1,036,000	9,630	59	81	111
Class II.	Div. I.	Chesnut (*Fagus castanea*) dry	.535	1,147,500	10,656	67	89	118
		Ditto, green	.875	924,570	8,100	54	68	85
		Ash (*Fraxinus excelsior*) dry	.753	1,525,500	14,130	89	119	160
		Elm (*Ulmus campestris*) dry	.544	1,343,000	9,720	78	82	86
		Acacia (*Robinia pseudo-acacia*) green	.820	1,687,500	11,227	98	95	92
	Div. II.	Spanish mahogany, dry	.853	1,255,500	7,560	73	67	61
		Honduras ditto, dry	.560	1,593,000	11,475	93	96	99
		Walnut (*Juglans regia*) green	.920	837,000	8,775	49	74	111
		Teak (*Tectona grandis*)	.744	2,167,074	12,915	126	109	94
		Poona, dry	.613	1,689,800	12,350	99	104	82
		Turtosa, or African Teak, dry	.954	1,728,000	17,200	101	144	138
		Poplar, (*Populus dilatata*) dry	.374	763,000	5,928	44	50	57
		Abele (*Populus alba*) dry	.511	1,134,000	10,260	66	86	112
	Div. III.	Cedar of Libanus (*Pinus cedrus*) dry	.486	486,000	7,420	28	62	106
		Riga fir (*Pinus sylvestris*) dry	.480	1,687,500	9,540	98	80	64
		Memel fir (ditto) dry	.544	1,957,750	9,540	114	80	56
		Mar Forest fir (ditto)	.684	845,066	7,323	49	61	76
		Planted Scotch fir (ditto) dry	.460	951,750	7,110	55	60	65
		Christiana white deal (*Pinus abies*) dry	.512	1,804,000	12,346	104	104	104
		American white spruce (*Pinus alba*) dry	.465	1,244,000	10,296	72	86	102
		Planted Spruce (*Pinus abies*) dry	.555	1,393,975	8,370	81	70	60
		Weymouth pine (*Pinus strobus*) dry	.460	1,633,500	11,835	95	99	103
		Pitch pine	.660	1,252,200	9,796	73	82	92
		Larch (*Pinus larix*) dry	.643	1,363,500	12,240	79	103	134
		Cowrie (*Dummara australis*)	.79	1,982,400	10,960	116	92	74

In the last three columns of this table, oak is made the standard of comparison.

For marble, being plentiful in Italy and France, these countries have been able to make a considerable use of it, even in the main walls of their edifices; but being seldom found in sufficient quantities, and of proper quality, in the more northern parts of Europe, it has been here chiefly confined to interior columns, pavements, chimney pieces, and sometimes stairs.

The kinds of stone are as various as the countries in which the buildings are constructed. Sand-stone being very generally found stratified, even in thin laminæ, being readily cut into different forms, and being, if properly selected and used, sufficiently durable, it has, in northern countries, been in most frequent use. It is a general accompaniment of coal strata, and is also often found where the latter does not occur. It varies in its component parts, being at different places argillaceous, siliceous, and calcareous. Its position in the earth assumes all directions, from the horizontal to a vertical plane. The proportional thickness of its strata, laminæ, or beds, varies from that of thin slate to many feet each. The upper beds are usually very thin or soft, or both; if sufficiently hard, they are employed in floor pavements, and for covering roofs. Under these the beds generally, in useful quarries, increase in thickness, hardness, and tenacity. The position of the laminæ always requires strict attention, that the worked stone may, if possible, be laid in the building upon its natural bed; for although some instances occur, as in the Isle of Portland and at Grinshill, in Shropshire, where the difference is not apparently great, yet in all stone (even granite) it is sufficiently well known to workmen. Some stone, as that of Bath, is so soft when taken out of the quarry as to be very conveniently worked with tools resembling those used by carpenters; yet when exposed for some time to the atmosphere, it becomes hard and durable. This last, indeed, cannot be deemed sand-stone, being nearly altogether calcareous.

Besides the before-mentioned, there is a very beautiful stone, dug in the hills near Dunstable, in the parish of Tottenhoe, from whence the stone receives its name. It has the appearance of indurated chalk. It is easily worked, and hardens by exposure to the weather. It should, however, be placed upon a plinth of some other stone, or kept by other means from contact with the ground; otherwise it is, in this situation, liable to be injured by the frosts. The house of the Duke of Bedford, at Woburn Abbey, is built chiefly with this stone, as are various other large houses in the neighbourhood of the quarries. Proofs of its durability may be seen in many old churches. From the closeness of its texture, the beauty of its colour, and the facility with which it is worked into mouldings, &c., it is peculiarly fit for house-building, both externally and internally.

The very perfect preservation of many beautiful churches in the countries of Lincoln, Rutland, and Northampton, are evidences of the excellence of the stone of which they are built.

In the central parts of Scotland, different varieties of sand-stone, which accompany coal, are used extensively in building houses, &c.; and this circumstance has not a little contributed to the fine appearance of the new streets, squares, and public buildings in the cities of Edinburgh and Glasgow. Flints, where they abound, and where other stone is scarce, are sometimes used in walls of considerable height; and notwithstanding their small size and irregularity of shape, are broken so as to compose a face of considerable smoothness. The church and steeple of Rickmansworth, in Hertfordshire, affords a fine specimen of this kind of building. But brick or squared stones are generally used as quoins of this sort of work.

In Scotland and Sweden, granite is made use of as a building material. It lies in large masses, generally separated by gunpowder into moderate, though still large dimensions, which are again cut into suitable scantlings, by means of iron instruments called *plugs and feathers*. They are not only worked into plain square forms, but also mouldings of considerable delicacy, by means of pointed tools, of different size and weights. At Aberdeen, in Scotland, where excellent granite is produced, and the working of it brought, perhaps, to the greatest perfection, there are handsome porticos, consisting of columns, bases, caps, and entablatures, executed in granite with great nicety. In the middle of the city, a public building, whose front is composed of a full Doric order, is wholly completed with this excellent material. There are two sorts of granite, the one gray and the other red; the last, being the hardest, is most difficult to work—consequently the former is most frequently employed; it consists of feldspar, mica, and quartz. It is much employed for paving the carriage-way of streets, and in the curbing of the flat side-pavements; also for piers and footpaths of bridges; and for facings and copings to quays and wharfs. At Aberdeen, it is employed in constructing very extensive piers, for protecting the entrance of the harbour; and in the Eddystone and Bell-rock lighthouse, it composes the facings, where they are exposed to the action of the sea.

Whin, basalt, and schistus, are also used in rubble work. The former dressing freely with the hammer, in one direction, may readily be formed with good faces, but not being stratified, their beds are uncertain, and not easily improved by art; the latter—that is, schistus—is just the reverse, having naturally good beds, but being in few instances willing to dress square across the laminæ: they are, indeed, where expense is not an object, worked to a face by the laborious operation of striking perpendicularly with a wedge-mouthed hammer or stone axe: both kinds are laid, sometimes promiscuously, and at others in regular courses.

Limestone, where found regularly stratified, affords good building stone, and combines the advantages of both the former, having naturally good beds, and dressing readily for a face.

A species of schistus affords a covering for roofs, totally unknown to the ancients, and which, when good of its kind, and properly prepared and laid on, is both very effectual and beautiful; for a farther account of which, *see* SLATE.

Bricks have, in England, become a material very generally employed in constructing all kinds of buildings. The country is provided by nature with abundant supplies of coal for burning bricks, which can, by means of the sea or numerous inland navigations, be, with great facility, conveyed to the large towns and populous districts, where the demand has long been very great. Clay of proper quality is usually found either upon the spot or immediate vicinity; a very limited number of workmen, properly arranged, can manufacture a great number of bricks in a stated time; these can readily be removed to the place where they are to be employed; being light to handle, and of a rectangular shape, the workmen lay them with facility and ease. By means of bricks, walls can be made much thinner than with almost any kind of stone; they are therefore cheaper, and occupy less space; in forming doorways, windows, chimneys, apertures, and angles of all kinds, the facility they afford is greater than that of any other durable material. A building whose walls are made with bricks dries soon, is free from damp; and, if properly made and thoroughly well burnt, bricks endure equal to most, and longer than many kinds of stone. For the best modes of manufacturing them, *see* BRICK.

Tiles having long been employed in England for covering

the roofs of buildings situated in towns, and of farm-houses and cottages in the country; but of late years the use of them has been much circumscribed by the extension of that of slates. For the mode of manufacturing and using them, *see* TILE.

Respecting sand, the ancient and modern practices agree nearly in all that need be said; that which is of an angular shade, hard texture, and perfectly free from earthy particles, is admitted to be best. For the circumstances necessary to be attended to in employing it, as well as lime, *see* CEMENT.

In regard to metals, in modern times, the use of copper and bronze has, for building purposes, been mostly abandoned. Brass has been continued in locks, pulleys, sash-windows, handles, sliding plates, connected with bells, and sundry other purposes in fitting up the interior of apartments.

Iron has been applied to many purposes unthought of in former times. The improvement and general introduction of cast-iron bids fair to create a totally new school of architecture. It has already been extensively employed in bridges, pillars, roofs, floors, chimneys, doors, and windows; and the facility with which it is moulded into different shapes will continue to extend its application. The before-mentioned purposes, to which it has already been applied, are more particularly noticed in the discussions of practice in the different branches of architecture, under their respective heads.

Glass, as a building material, was little if at all known to the ancients; and its introduction alone has been productive of comforts and elegances to which the most refined of the Greeks and Romans were utter strangers. Their oiled paper, transparent horn, talc, shells, and linen, would now, even to an English peasant, appear a miserable expedient. For an account of its manufacture, and application to architectural purposes, *see* GLASS.

Besides the materials which have already been enumerated as composing the principal members, as walls, roofs, floors, doors, windows, chimneys, stairs, and pavements; hair is also necessary in the composition of mortar for plastering the surface of walls and ceilings; likewise various paints and papers, for covering them and other parts of the work; all which are described, with the modes of applying them, in their proper places.

MATHEMATICS (from the Greek *μαθηματικὴ*), the science which treats of the ratio and comparison of quantities, whence it is defined the *science of ratios;* some writers call it the *science of quantities;* but this is inacurate, since quantities themselves are not the subject of mathematical investigation, but the ratio which such quantities bear to each other.

The term *mathematics* is derived from *μαθησις*, *mathesis*, discipline, science, representing with justness and precision, the high idea that we ought to form of this branch of human knowledge. In fact, mathematics are a methodical concatenation of principles, reasonings, and conclusions, always accompanied by certainty, as the truth is always evident, an advantage that particularly characterizes accurate knowledge and the true sciences, with which we must be careful not to associate metaphysical notions, conjectures, nor even the strongest probabilities.

The subjects of mathematics are the comparisons of magnitude, as numbers, velocity, distance, &c. Thus, geometry considers the relative magnitude and extension of bodies; astronomy, the relative velocities and distances of the planets; mechanics, the relative powers and force of different machines, &c. &c., some determinate quantity being fixed upon in all cases, as a standard of measure.

The study of mathematics is highly useful to the architect, particularly arithmetic, geometry, mensuration, and mechanics. Geometry enables him to take his dimensions under the most difficult circumstances, and to lay out the various parts of his design, while it furnishes him with rules for executing the same. Mensuration is the application of arithmetic to geometry, and shows him how to find the exact proportion of his labour, according to the difficulty of executing a certain uniform portion of a work, and to estimate the quantity of materials employed therein: that branch of mathematics called *mechanics*, enables him to compute the strength and strain of the materials he employs. In short, without the aid of mathematics, he is unfit for his profession; and the more he understands, the fewer difficulties he will have to encounter in the prosecution of his art.

Mathematics are naturally divided into two classes; the one comprehending what we call *pure* and *abstract;* and the other the *compound* or *mixed*. Pure mathematics relate to magnitudes generally, simply, and abstractedly, and are therefore founded on the elementary ideas of quantity. Under this class are included arithmetic, or the art of computation; geometry, or the science of mensuration and comparison of extensions of every kind; analysis, or the comparison of magnitudes in general; to which we may add geometrical analysis, which is a combination of the two latter. Mixed mathematics are certain parts of physics, which are, by their nature, susceptible of being submitted to mathematical investigation. We here borrow from incontestable experiments, or otherwise suppose bodies to possess some principal and necessary quality, and then, by a methodical and demonstrative chain of reasoning, deduce from the principles established conclusions as evident and certain as those which pure mathematics draw immediately from axioms and definitions, observing, that these results are always given with reference to the experiments on which they are founded, or the hypothesis which furnished the first datum. To illustrate this by an example: numberless experiments have shown us, that all bodies near the earth's surface fall with an accelerated velocity, and that the spaces passed through are as the squares of the time they have occupied in falling. This, then, the mathematician considers as a necessary and essential quality of matter, and with this datum he proceeds to examine what will be the velocity of a body after any given time, in what time it will have acquired a given velocity, what time is necessary for it to have generated a given space, &c., and in all these investigations his conclusions are as certain and indisputable as any of those which geometry deduces from self-evident truths and definitions. Again, in optics, having established it as a principle of light, that it is transmitted in right lines while no obstacle is opposed to the passage of the rays; that when they become reflected, the angle of incidence is equal to the angle of reflection; that in passing from one medium to another, of different density, they fly off from their first direction, but still follow a certain geometrical law; these principles, or qualities of light, being once admitted, whatever may be its nature, be it material or immaterial, or whatever may be the medium through which it passes, or the surface by which it is reflected, are matters totally indifferent to the mathematician; he considers the rays only as right lines, the surfaces on which they impinge as geometrical planes, of which the form only enters into his investigation: and from this point all his inquiries are purely geometrical, his investigation clear and perspicuous, and his deduction evident and satisfactory. To this class of mathematics belong mechanics, or the science of equilibrium and motion of solid bodies: hydrodynamics, in which the equilibrium and motion of fluids are considered; astronomy, which

relates to the motion, masses, distance, and densities, of the heavenly bodies; optics, or the theory and effects of light; and, lastly, acoustics, or the theory of sounds.

Such are the subjects that fall under the contemplation of the mathematician; and, as far as a knowledge of these may be considered beneficial to mankind, so far, at least, the utility of the science on which they depend, must be admitted. It is not, however, the application of mathematics to the various purposes of society, that constitutes their particular excellency; it is their operation upon the mind, the vigour they impart to our intellectual faculties, and the discipline which they impose upon our wandering reason. "The mathematics," says Dr. Barrow, "effectually exercise, not vainly delude, nor vexatiously torment studious minds with obscure subtilties, but plainly demonstrate everything within their reach, draw certain conclusions, instruct by profitable rules, and unfold pleasant questions. These disciplines also inure and corroborate the mind to a constant diligence in study; they wholly deliver us from a credulous simplicity, and most strongly fortify us against the vanity of scepticism; they effectually restrain us from a rash presumption, most easily incline us to a due assent, and perfectly subject us to the government of right reason. While the mind is abstracted and elevated from sensible matter, it distinctly views pure forms, conceives the beauty of ideas, and investigates the harmony of proportions; the manners themselves are sensibly corrected and improved, the affections composed and rectified, the fancy calmed and settled, and the understanding raised and excited to more divine contemplations."

List of the most celebrated Mathematicians, with the names of their works, or the sciences in which they were eminent, and the countries where they flourished; chronologically arranged.

B. C.	Name.	Science.	Country.
960	Chiron the Centaur.	Astronomy	Thessaly
747	*Era of Nabonassar*		Babylon
722	Confucius	Ethics	China
600	Thales	Prediction of an Eclipse	Greece
	Anaximander	Celestial Globes	Ditto
500	Cleostratus	Astronomy	Ditto
	Anaxagoras	Philosophy	Ditto
	Anaximenes	Sun-dial	Ditto
	Pythagoras	47 Euc. Syst. of Astron.	Ditto
400	Euctemon	Astronomy	Ditto
	Meton	Metonic Cycle	Ditto
	Plato	Geometry and Philos.	Ditto
	Hippocrates	Quadrant of Lunes	Ditto
	Œnopides	Geometry	Ditto
	Zonodorus	Ditto	Ditto
300	Aristotle	Philosophy	Ditto
	Calippus	Astronomy	Ditto
	Dinocrates	Architecture	Ditto
	Theophrastus	History and Mathem.	Ditto
	Xenocrates	Architecture	Ditto
	Eudoxus	Geometry and Astron.	Ditto
	Pytheas	Navigation and Astron.	Gaul
	Archytas	Mathematics & Philos.	Greece
	Aristæus	Conic Sections	Ditto
	Dinostratus	Quadratix	Ditto
	Menechmus	Geometry	Ditto
200	Apollonius	Geometry & Conic Sect.	Ditto
	Archimedes	Geometry & Mechanics	Sicily
	Aristarchus	Astronomy	Greece
	Eratosthenes	Measure of a Degree	Ditto
	Euclid	Elements of Geometry and Optics	Ditto
	Aratus	Poetry and Astronomy	Greece
	Aristillus	Philosophy and Astron.	Ditto
	Nicomedes	Conchoid	Ditto
100	Hipparchus	Length of Year, Number of the Stars	Ditto
	Ctesibius	Water Pumps	Ditto
	Hero	Hero's Foun. Clepsydra	Egypt
	Manilius	Poetry and Astronomy	Rome
	Manlius	Astronomy	Ditto
	Julius Cæsar	Calendar reformed	Ditto
	Sosigenes	Astronomy	Egypt
	Posidonius	Mechanics & Mathem.	Rome
	Theodosius	Spherics	Ditto
A. D.			
0	Cleomedes	Astronomy	Ditto
	Geminus	Geometry & Astronomy	Rhodes
	Vitruvius	Architecture	Rome
	Menelaus	Spherical Trigonometry	Ditto
100	Frontinus (Sixtus)	Enginery	Rome
	Nicomachus	Mathematics	Greece
	Hypsicles	Ditto	Ditto
	Ptolemy	Almagest	Egypt
200	Diophantus	Diophan. Analysis	Greece
300	Iamblicus	Philosophy	Syria
	Pappus	Geometrical Loci	Greece
	Theon	Philosophy	Ditto
400	Hypati, daughter of Theon	Commentary on Diophanes	Ditto
	Proclus	Commentary on Euclid	Ditto
	Diocles	Cissoid	Ditto
	Serenus	Geometry	Ditto
500	Marinus	Ditto	Naples
	Anthemius	Architecture; Domes.	Rome
	Eutocius	Geometry	Greece
	Isidorus	Architecture	Rome
600	The Venerable Bede		England
642	*Alexandrian Library destroyed.*		
700	Almansor, the Victorious	Astronomy	Saracen
	Hero the Younger	Geometry	Greece
800	Almaimon, Calif	Astronomy	Arabia
	Alraschid	Ditto	Persia
	Alwamon	Ditto	Ditto
	Alfragan	Ditto	Arabia
	Albategni	Ditto	Ditto
	Thebit Ibn Chora	Ditto	Ditto
900	(Gebert) Silvester II	Mathematics	Spain
1000	Ibn Ionis	Astronomy	Arabia
	Geber Ben Alpha	Comment on Almagest	Ditto
1100	Alhazen	Optics and Astronomy	Ditto
1200	Leonard (de Pisa)	First Euro. Algebraist	Italy
	Nassir Eddin	Astronomy	Persia
	Alphonso, King of Castile	Alphonsine Tables	Spain
1200	Halifax, or Sacrobosco	Mathematics	England
	Jordanu Nemorarius	Mathematics	
	Bacon	Philosophy	England
	Campanus	Theory of Planets	
	Vitella and Pecam	Optics	
1300	Albano	Physic & Mathematics	Italy
	Ascoli	Mathematics	Ditto
	John of Saxony	Astronomy	
1400	Bianchini	Ditto	Ditto
	Moscholpulus, Mod.	Magic Square	Greece
	Purbach	Astronomy	Vienna

A.D.	Name.	Science.	Country
1400	Regiomontanus	Ditto	Ditto
	Cusa, Cardinal	Astronomy	
	Henry, Duke of Visco	Sea Charts	
	Uleugh Beigh, Prince	Astronomy	Tartary
	Bernard of Granolachi	Ditto	
	Lucas de Burgo	Geometry & Algebra	
	Novera, Domini	Astronomy	Italy
1500	Copernicus	System of Astronomy	Germany
	Apian, Peter	Math. & Cosmogony	Ditto
	Apian, Philip	Sun-dials	Ditto
	Buteo	Geometry	France
	Cardan	Ditto	Italy
	Commandine	Mathematics	Ditto
	Durer, Albert	Geom. & Perspective	Germany
	Vieta	Angular Sections	France
	Brahe, Tycho	Astronomy	Denmark
	Bacon, Lord Francis	Philosophy	England
	Galileo	Law of falling Bodies	Italy
1600	Briggs	Present System of Logarithms	England
	Des Cartes	Equation of Curve Lines	France
	Kepler	Laws of Celes. Motion	Germany
	Napier	Logarithms	Scotland
	Torricelli	Gravity of Atmosph.	Italy
	Cavalerius	Indivisibles	Milan
	Brounker	Continued Fractions	Ireland
	Fermat	Max. et Min. Theory of Numbers	France
	Pascal	Doct. of Probabilities	Ditto
	Wallis	Arithmet. of Infinites	England
	Bernouilli, James	Mathematics	Swiss
	Barrow	Ditto	England
	Hooke	Philos. & Mechanics	Ditto
	Huygens	Evolute of Curves	Holland
	Leibnitz	Differential Calculus	Germany
	L'Hôpital	Mathematics	France
	Roemer, Dan.	Progress. Mot. of Light	Denmark
1700	Newton, Sir I.	Various	England
	Bernouilli, John	Mathematics	Swiss
	Bradley	Aberration of Stars	England
	Cotes	Mathematics	Ditto
	Taylor	Increments	Ditto
	Clairaut	Mathematics	France
	Maclaurin	Ditto	Scotland
	De Moivre	Ditto	England
	Simpson	Ditto	Ditto
	D'Alembert	Partial Differences	France
	Euler	Mathematics	Germany
	Landen	Residual Analysis	England
	Waring	Mathematics	Ditto

Besides the foregoing, who were mostly celebrated in the branches affixed to their names, the following were so multifarious in their studies and productions, that it would be injustice to their talents to give a preference by noticing any one to the exclusion of the rest. We therefore merely subjoin a list of their names, and the countries in which they were born.

A.D.	Name.	Country.	A.D.	Name.	Country.
1500	Maurolycus	Sicily	1500	Ramus	France
	Nonius	Portugal		Recorde	Ditto
	Sturmius	France		Reinhold	Germ.
	Tartaglia	Venice		Rothman	Ditto
	Werner	Germany		Stiffelius	Ditto
	Ferrari	Italy		Ubaldi, Guido	Italy
	Mercator	Denmark		Porta, Baptista	Naples
	Byrgious	Italy	1700	Brackenridge	England
	Clavius	Ditto		Cassini, D. & J.	Nice
	Castel	France		Craig, J.	Scotland
1600	Bayer	Prussia		Gravesande	Holland
	Beauregard	France		Hire, Philip De la	France
	Beaume, De	Italy		Keill	Scotland
	De Dominis	Ditto		Laloubere	France
	Gassendi	France		Lomsberg	
	Gellibrand	England		Manfredi	Italy
	Gundling	Germany		Marchetti	Ditto
	Halifax, or Longomontanus	Denmark		Meibomius	Germany
	Harriot	England		D'Omerique, H	France
	Horrox	Ditto		Pemberton	England
	Kircher	Germany		Prestet	France
	Lucas Valerius	Italy		Saunderson	England
	Metius	Holland		Saurin	France
	Oughtred	England		Stirling	Scotland
	Pitiscus, Barthelemi	Germany		Ulloa	Spain
	Romanus	Flanders		Varignon	France
	Ursinus	Germany		Verbiest	
	Bartholin	Denmark		Wolfius	Prussia
	Borelli	Naples		Bellidor	
	Bullialdus			Bernouilli, Js. Jn. & Daniel	Swiss
	Dechales	Savoy		Bougainville	France
	Frenicle	France		Boguer	
	Girard, Albert	Holland		De la Caille	France
	Gregory, J. & D.	England		Clarke, Dr. S.	England
	Henrion	France		Collins	Ditto
	Hevelius	Poland		Courtivron	France
	Horrebow	Denmark		Cramer	Geneva
	Mersennus	France		Dodson	England
	Riccioli	Italy		Dollond	Ditto
	Roberval	France		Fatio	
	Slusius	Flanders		Fountain	England
	Snellius, R. & W.	Holland		Goldbach	
	Tacquet	France		Guisnée	
	Tchirnhausen			Herman	Swiss
	Vincent, St. Gré			Halley	England
	Viviani	Tuscany		Jacquier	France
	Vlacq			Koenig	Swiss
	Ward, Seth	England		Long	France
	Witt, John de	Holland		M'Laurin	Scotland
	Amontons	France		Mairan	France
	Auzout	Ditto		Mariotte	Ditto
	Bachet	Ditto		Maupertuis	Ditto
	Fagnani	Italy		Mayer	Germany
	Flamsteed	England		Montmort	France
	Grimaldi	Italy		Nicole	Ditto
	Guido Grandi	Ditto		Riccati	Italy
	Hudde	Holland		Robins	
	Keri	Hungary		Simson	England
	Kinghuysen			Walmsley	
	Lagnay	France		Agnesia Donna	Spain
	Lieutard	Ditto		Atwood	England
	Meraldi	Italy		Bailly	France
	Molyneux	Ireland		Bezout	Ditto
	Oldenburgh	Bremen		Borda	Ditto
	Ozanam	France		Carnot	Ditto
	Pell	England		Emerson	England
	Picart	France		Horsley	Ditto
	Reyneau	Ditto		Harris	Ditto
	Schooten	Holland		Herschel	Ditto
	Wren	England			
1700	Billi, De	France		Kestner	

A.D.	Name.	Country.	A.D.	Name	Country.
1700	Lalande . .	France	1700	Steward . .	Scotland
	Maskelyne .	Ditto		Vandermond .	
	Montucla .	Ditto		Vega . . .	
	Pingree . .	Ditto		Wargentin .	
	Robison . .	Scotland			

MATHEMATICAL INSTRUMENTS, see INSTRUMENTS.

MAUSOLEUM, is the term now generally used to designate a sepulchral chapel or edifice erected for the reception of a monument; but it originally applied only to the magnificent structure raised by Artemisia, as the tomb of her husband Mausolus, king of Caria, at Halicarnassus, B.C. 352. Of this monument, once reckoned among the wonders of the world, no remains now exist; but from Pliny's description (xxxvi. 5,) it appears to have been nearly square in its plan, measuring 113 feet on its sides, and 93 on each of its ends or fronts, and to have been decorated with a peristyle of 36 columns (supposed by Hardouin to have been 60 feet, or upwards), above which the structure was carried up in a pyramidal form, and surmounted, at its apex, by a marble quadriga, executed by Pythis, who, according to Vitruvius, was joint architect with Satyrus in the building. It was also richly decorated with sculptures and reliefs, by Scopas, Bryaxis, Timotheus, and Leochares. The entire height was 140 feet.

The mausoleum erected at Babylon by Alexander the Great, in honour of Hephæstion, appears to have been still more magnificent, and somewhat extravagant in its decorations, as far as can be gathered from the account of it by Diodorus (xvii. 115). Below it was adorned by the gilded rostra, or beaks, of 240 ships, and every successive tier or story was enriched with a profusion of sculpture, representing various animals, fighting centaurs, and other figures, all of which were gilt. On the summit were statues of sirens, made hollow, in order that the singers who chanted the funeral dirge might be concealed within them.

Those of Augustus and Hadrian, at Rome, were also structures of great magnitude and grandeur, and resembled each other in form, being circular on the plan. The first stood in the Campus Martius, where remains of it yet exist in the two concentric circles forming the first and second stories of the building, and the vaulted chambers between, which supported the first or lowest terrace. Of these terraces there were three, consequently four stages in the building, gradually decreasing in diameter, the uppermost of which was crowned by a colossal statue of the emperor. The terraces themselves were planted with trees. From traces of something of the kind that yet remain, it is conjectured that there was originally an advanced portico attached to the building, in the same manner as that of the Pantheon, though considerably smaller in proportion to the rest of the plan, as it could not have been carried up higher than the first stage of the building. According to Hirt's representation of it, in his "Baukunst bei den Alten," it was a Corinthian hexastyle, advanced one intercolumn before the side-walls connecting it with the circular edifice behind it.

Hadrian's mausoleum, now converted into the Castello di St. Angelo, in which shape it is familiar to almost every one, is a work of most massive construction, and originally presented an unbroken circular mass of building, erected upon a larger square basement, lofty in itself, yet of moderate height in proportion to the superstructure, the latter being about twice as high as the former. This nearly solid rotunda, which was originally coated with white marble, had on its summit numerous fine statues, which were broken to pieces, and the fragments hurled down by the soldiers of Belisarius upon the Goths, who attempted to take the building by storm. Neither are any remains now left of the uppermost stage of the edifice, which assumed the form of a circular peripteral temple, whose diameter was about one-third of the larger circle. According to tradition, its peristyle consisted of the 24 beautiful Corinthian columns, which afterwards decorated the basilica of San Paulo fuori delle Mura (partially destroyed some years ago by fire, but now nearly restored); and its tholus or dome was surmounted by a colossal pine-apple in bronze, now placed in the gardens of the Vatican.

Such places as Henry VII.'s chapel, and the Pantheon of the Escurial, may also be considered as mausoleums; but the term is generally restricted to a detached edifice erected merely as a private burying-place, or to contain tombs. There are several structures of the kind in the parks of our nobility; among the most remarkable is that at Castle Howard, the seat of the earl of Carlisle, and one of Hawksmoor's best works, a noble circular edifice in the Roman-Doric style, elevated upon a basement, and crowned by a dome: plans, sections, &c. of this structure have been beautifully engraved by Moses. The marquis of Rockingham's mausoleum, by Carr, is another ornamental structure of the kind, composed of three stories, Doric, Ionic, and Corinthian. We may also mention those at Cobham, in Kent, and Brocklesby, in Lincolnshire, by the late James Wyatt. The mausoleum of Louisa, queen of Prussia, at Charlottenburg, near Berlin, has a Grecian-Doric portico, but is not so remarkable as a building as for containing the sarcophagus, on which is the recumbent figure of that princess, the chef d'œuvre of Rauch's chisel.

MEASURE (from the Latin *mensura*), in geometry, any certain quantity assumed as one, or unity, to which the ratio of other homogeneous or similar quantities is expressed.

This definition is somewhat more agreeable to practice than that of Euclid, who defines measure as "a quantity, which, being repeated any number of times, becomes equal to another;" which only answers to the idea of an arithmetical measure, or quota part.

MEASURE OF AN ANGLE, an arc described from the vertex in any place between its legs. Hence angles are distinguished by the ratio of the arcs, described from the vertex between the legs, to the peripheries.

Angles, then, are distinguished by those arcs; and the arcs are distinguished by their ratio to the periphery. *See* ANGLE.

It is, however, in many cases, a more simple and more convenient method to estimate angles, not by the arcs subtending them, but by their sines, or the perpendicular falling from one leg to the other. Thus it is usual, among those who are taking the level of the ground, to say that it rises or falls one foot, or one yard, in ten, when the sine of the angle of its inclination to the horizon is one-tenth of the radius. Angles of different magnitudes, are, indeed, proportional to the arcs, and not to the sines; so that in this sense the sine is not a true measure of the comparative magnitude of the angle; but in making calculations, we are more frequently obliged to employ the sine or cosine of an angle than the angle or arc itself. Nevertheless it is easy to pass from one of these elements to the other, by means either of trigonometrical tables, or of the scales engraved on the sector.

MEASURE OF A FIGURE, OR PLANE SURFACE, a square, whose side is one inch, foot, yard, or other determinate length.

Among geometricians it is usually a rod, called a *square rod*, divided into ten square feet, and the square feet into square digits. Hence square measures. See MENSURATION.

MEASURE of FORCE, *for perforating metal and other substances.* The measure of the force necessary to punch a hole

through a plate of metal or other substance, must be an interesting subject to scientific readers. We shall therefore here insert the result of Mr. Bevan's experiments made on that subject. A good cylindrical steel punch was made and fitted to a guide or director, so as to move correctly to a cylindrical hole in a steel plate connected with the guide; with this instrument, the artist was able to force cylinders of metal very uniform, and with little or no bur to the hole, both by simple pressure and percussion. The results of some experiments made on the force of simple pressure, to make a hole through a metal plate of one-eighth of an inch in thickness, and one-fourth of an inch in diameter, are as follows:—Plate iron, 3,900 lbs.; cast brass, 3,200 lbs.; hammered brass, 3,600 lbs.; copper, 2,800 lbs. The following are the results from the same machine, on specimens of wood, in the direction of the grain, of the same thickness and diameter:—Christiana deal, 135 lbs.; mahogany, 170 lbs.; dry boxwood, 356 lbs.; beech, 204 lbs.; ash, 197 lbs.; oak, 156 lbs.; elm, 122 lbs.

Measure of a Line, any right line taken at pleasure, and considered as unity.

Measures, *Line of*, see Line.

Measure of the Mass, or Quantity of Matter, in mechanics, is its weight; it being apparent, that all the matter which coheres and moves with a body, gravitates with it; and it being found by experiment that the gravities of homogeneal bodies are in proportion to their bulks: hence, while the mass continues the same, the absolute weight will be the same, whatever be its figure; but as to its specific weight, it varies as the quantity of surface varies. *See* Weight.

Measure of a Number, in arithmetic, a number which divides another, without leaving any fraction; thus 9 is a measure of 27.

Measure of a Solid, a cube whose side is one inch, foot, yard, or other determined length.

Among geometricians it is sometimes a rod, or perch, called a *cubic perch*; divided into cubic feet, digits, &c. Hence cubic measures, or measures of capacity. *See* Cube and Mensuration.

Measure of Velocity, in mechanics, the space passed over by a moving body in any given time. To measure a velocity, therefore, the space must be divided into as many equal parts as the time is conceived to be divided into. The quantity of space answering to such an interval of time is the measure of the velocity.

Measure, *Universal and Perpetual*, a kind of measure unalterable by time, to which the measures of different nations and ages might be reduced, and by which they might be compared and estimated. Such a measure is very desirable, if it could be attained. Huygens, in his *Horol. Oscill.*, proposes, for this purpose, the length of a pendulum vibrating seconds, taken from the point of suspension to the point of oscillation. The third part of such a pendulum may be called the *horary foot*, and serve as a standard to which the measure of all other feet may be preferred. Thus, *e. g.* the proportion of the Paris foot to the horary foot would be that of 864 to 881; because the length of three Paris feet is 864 half lines, and the length of a pendulum vibrating seconds contains three horary feet, or 3 feet $8\frac{1}{2}$ lines, *i. e.* 881 half lines. But this measure, in order to its being universal, supposes, that the action of gravity is everywhere the same, which is contrary to fact; and, therefore, it would really serve only for places under the same parallel of latitude; and in order to its being perpetual, it supposes that the action of gravity continues always the same in the same place.

Measure, in a legal, commercial, and popular sense, denotes a certain quantity or proportion of anything bought, sold, valued, or the like. It denotes also a vessel of capacity employed in measuring grain and other articles: the fourth part of a peck. The regulation of weights and measures ought certainly to be the same throughout the kingdom, and therefore be reducible to some fixed rule or standard; the prerogative of so fixing it was vested, by our ancient law, in the crown. This standard was originally kept at Winchester; and we find, in the laws of king Edgar, cap. 8, near a century before the Conquest, an injunction, that the one measure, which was kept at Winchester, should be observed throughout the realm. With respect to measures of length, our ancient historians (Wil. Malm. *in Vita. Hen. I.* Spelm. *Hen. I. apud Wilkins*, 299) inform us, that a new standard of longitudinal measure was ascertained by king Henry I., who commanded that the ulna, or ancient ell, which answers to the modern yard, should be made of the exact length of his own arm; and one standard of measures of length once gained, all others are easily derived from hence: those of greater length by multiplying; those of less by subdividing the original standard. Thus, by the statute called "*Compositio ulnarum et perticarum*," $5\frac{1}{2}$ yards make a perch; and the yard is subdivided into 3 feet, and each foot into 12 inches, which inches will be each of the length of 3 grains of barley. The standard of weights was originally taken from corns of wheat, whence the lowest denomination of weights which we have still expressed by a "grain," 32 of which are directed by the statute called "*Compositio mensurarum*," to compose a pennyweight, of which 20 make an ounce, 12 ounces a pound, and so upwards. Upon these principles the standards were first made, which, being originally so fixed by the crown, their subsequent regulations have been generally made by the king in parliament. Thus, under king Richard I., in his parliament holden at Westminster, A. D. 1197, it was ordained that there should be only one weight and one measure throughout the kingdom, and that the custody of the assize, or standard of weights and measures, should be committed to certain persons in every city and borough. In king John's time, this ordinance of king Richard was frequently dispensed with for money (Hoved. A. D. 1201), which occasioned a provision to be made for enforcing it, in the great charters of king John and his son. —*Stat.* 9. *Hen. III. c.* 25.

The statute of Magna Charta, cap. 25, ordains that there shall be but one measure throughout England, according to the standard in the Exchequer, which standard was formerly kept in the king's palace; and in all cities, market-towns, and villages, it was kept in the churches. (4 Inst. 273.) By 16 Car. I. cap. 19, there is to be one weight and measure, and one yard, according to the king's standard; and whoever shall keep any other weight or measure, whereby anything is bought or sold, shall forfeit for every offence five shillings; and by 22 Car. II. cap. 8, water measure (viz., five pecks to the bushel), as to corn, or grain, or salt, is declared to be within the statute 16 Car. I.; and if any sell grain, or salt, &c., by any other bushel or measure than what is agreeable to the standard in the Exchequer, commonly called Winchester measure, he shall forfeit 40s. (22 Car. II. c. 8. 22 and 23 Car. II. c. 12.) Notwithstanding these statutes, in many places and counties there were, till within the last few years, many different measures of corn and grain, and also of length and solidity. Great inconvenience being felt in consequence, the government at length interfered, and introduced a bill into parliament for the establishment of a uniform system throughout the country.

This system, called the Imperial, came into operation on the 1st May, 1825, on which day a total alteration took place

in the weights and measures hitherto used in Great Britain. The principles upon which this alteration was founded we shall now proceed briefly to describe.

The Rationale of the Imperial System.—Take a pendulum which will vibrate seconds in London, on a level of the sea, in a vacuum; divide all that part thereof which lies between the axis of suspension and the centre of oscillation into 391·393 equal parts; then will ten thousand of those parts be an imperial inch, twelve whereof make a foot, and thirty-six whereof make a yard.

The *Standard Yard* is "that distance between the centres of the two points in the gold studs in the straight brass rod, now in the custody of the clerk of the House of Commons, whereon the words and figures 'standard yard, 1760,' are engraved, which is declared to be the genuine standard of the measure of length called a yard; and as the expansibility of the metal would cause some variation in the length of the rod in different degrees of temperature, the act determines that the brass rod in question shall be of the temperature of 62 degrees Fahrenheit. The measure is to be denominated the 'imperial standard yard,' and to be *the only standard whereby all other measures of lineal extension shall be computed.* Thus the *foot*, the *inch*, the *pole*, the *furlong*, and the *mile*, shall bear the same proportion to the imperial standard yard as they have hitherto borne to the yard measure in general use." The act also makes provision for the restoration of the standard yard, in case of loss, destruction, or defacement, by reference to an *invariable* natural standard, which is to be that proportion which the yard bears to the length of a pendulum vibrating seconds of time in the latitude of London, in a vacuum at the level of the sea, which is found to be as 36 inches (the yard) to 391·393 (the pendulum); thus a sure means is established to supply the loss which might by possibility occur.

Take a cube of one such inch of distilled water at 62° of temperature by Fahrenheit's thermometer; let this be weighed by any weight, and let such weight be divided into 252·458 equal parts, then will one thousand of such parts be a troy grain; and seven thousand of those grains will be a pound avoirdupois, the operation having been performed in air. Ten pounds such as those mentioned, of distilled water, at 62° of temperature, will be a gallon, which gallon will contain two hundred and seventy-seven cubic inches, and two hundred and seventy-four one-thousandth parts of another cubic inch.

The Standard Pound is determined to be that standard pound *troy* weight made in the year 1758, in the custody of the clerk of the House of Commons: such weight is to be denominated the "imperial standard troy pound;" and after the first of May, 1825, is to be "*the only standard measure of weight, from which all other weights shall be derived, computed, and ascertained*, and that one twelfth part of the said troy pound shall be *an ounce*, and one twentieth part of such ounce shall be *a pennyweight*, and that one twenty-fourth part of such pennyweight shall be *a grain;* so that 5760 such grains shall be *a pound troy*, and 7000 such grains shall be declared to be *a pound avoirdupois*, and one sixteenth part of the said pound avoirdupois shall be *an ounce avoirdupois*, and one sixteenth part of such ounce shall be *a drachm.*"

If the standard pound shall be lost, destroyed, or defaced, the act directs that it shall be recovered by reference to the weight of a cubic inch of water: it having been ascertained that a cubic inch of distilled water, weighed in air by brass weights, at the temperature of 62° Fahrenheit, and the barometer at 30 inches, is equal to 252·458 grains; and, as the standard troy pound contains 5760 such grains, it is therefore established that the original standard pound may be at any time recovered by making another weight to bear the proportion just mentioned to a cubic inch of water.

The Standard Gallon is determined by the act to be such measure as shall contain ten pounds avoirdupois of distilled water, weighed in air, at the temperature of 62° Fahrenheit, and the barometer at 30 inches, and such measure is declared to be the "imperial standard gallon, and shall be the unit and *only standard measure of capacity to be used, as well for wine, beer, ale, spirits, and all sorts of liquids, as for dry goods not measured by heaped measure;* and that other measures shall be taken in parts, or multiples, of the said imperial standard gallon—the quart being the fourth part of such gallon, and *the pint* one eighth part—two such gallons making *a peck*, eight such gallons *a bushel*, and eight such bushels *a quarter* of corn, or other dry goods not measured by heaped measure.

The Standard for Heaped Measure, for such things as are commonly sold by heaped measure, such as coal, culm, lime, fish, potatoes, fruit, &c., shall be "*the aforesaid bushel*, containing eighty pounds of water, as aforesaid, the same being made round with a plane and even bottom, and being 19½ inches from outside to outside;" and goods thus sold by heaped measure shall be heaped "in the form of a cone, such cone to be of the height of at least six inches, the outside of the bushel to be the extremity of the base of such cone;" three such bushels shall be a *sack*, and twelve such sacks shall be a *chaldron.*

Stricken Measure.—The last mentioned goods may be sold either by the heaped measure, or by the standard weight as before mentioned; but all other kinds of goods not usually sold by heaped measure, which may be sold or agreed for by measure, the same standard measure shall be used; but it shall not be heaped, but stricken with a round stick or roller, straight, and of the same diameter from end to end.

N.B.—Copies and models of the standard of length, weight, and measure, are to be made and verified under the direction of the Treasury, and every county to be supplied with them for reference whenever required; and after the first of May, 1825, all contracts for sale, &c., by weight or measure, shall relate to the standard, unless the contrary is specified. Existing weights and measures may be used, being marked so as to show the proportion they have to the standard measures and weights. Tables of equalization of the weights to be made by the Treasury; tables, also, for the customs and excise, by which the duties will be altered so as to make them equal to what they are at present, in consequence of the alterations in the weights and measures. *See* WEIGHTS.

The following extracts from the bill for ascertaining and establishing uniformity of weights and measures will explain this subject fully:—"Whereas it is necessary, for the security of commerce, and for the good of the community, that weights and measures should be just and uniform; and whereas, notwithstanding it is provided by the great charter, that there shall be but one measure and one weight throughout the realm; and, by the treaty of union between England and Scotland, that the same weights and measures should be used throughout Great Britain as were then established in England; yet different weights and measures, some larger and some less, are still in use in various places throughout the United Kingdom of Great Britain and Ireland; and the true measure of the present standard is not verily known, which is the cause of great confusion and of manifest frauds; for the remedy and prevention of those evils for the future, and to the end that certain standards of weights and measures should be established throughout the United Kingdom of Great Britain and Ireland,

"Be it therefore enacted, by the king's most excellent majesty, by and with the consent of the lords spiritual and temporal, and commons, in this present parliament assembled, and by the authority of the same, that a cubic inch of distilled water in a vacuum, weighed by brass weights, also in a vacuum, at the temperature of 62° of Fahrenheit's thermometer, is equal to two hundred and fifty-two grains and seven hundred and twenty-four thousandth parts of a grain.

"And be it further enacted, that the standard measure of capacity, as well for liquid as for dry goods not measured by heaped measure, shall be the gallon containing ten pounds avoirdupois weight of distilled water, weighed in air, at the temperature of 62° of Fahrenheit's thermometer, the barometer being at thirty inches, to be used as well for wine, beer, ale, spirits, and all sorts of liquids, as for dry goods not measured by heaped measure; and eight such gallons shall be a bushel, and eight such bushels a quarter—of corn, or other dry goods not measured by heaped measure.

"And be it further enacted, that the standard measure of capacity for coals, culm, lime, fish, potatoes, or fruit, and all other goods and things commonly sold by heaped measure, shall be the aforesaid bushel, containing eighty pounds avoirdupois of water as aforesaid, the same being made round with a plane and even bottom, and being nineteen and a half inches from outside to outside of such standard measure as aforesaid.

"And be it further enacted, that all contracts, bargains, sales, and dealings, which shall be made or had within any part of the United Kingdom of Great Britain and Ireland, for any work to be done, or for any goods, wares, merchandise, or other thing to be sold, delivered, done, or agreed for, by weight or measure, where no special agreement shall be made to the contrary, shall be deemed, taken, and construed, to be made and had according to the weights and standard measures ascertained by this act; and in all cases where any special agreement shall be made, with reference to any weight or measure established by any local custom, the ratio or proportion which every such local weight or measure shall bear to any of the said standard weights or measures, shall be expressly declared and specified in such agreement, or otherwise such agreement shall be null and void.

"And whereas it is expedient, that persons should be allowed to use the several weights and measures which they may have in their possession, although such weights and measures may not be in conformity with the standard weights and measures established by this act; be it therefore enacted, that it shall and may be lawful for any person or persons to buy and sell goods and merchandise by any weights or measures, established either by local custom or founded on special agreement; provided always, that in order that the ratio or proportion which all such measures and weights shall bear to the standard weights and measures established by this act, shall be and become a matter of common notoriety, the ratio or proportion which all such customary measures and weights shall bear to the said standard measures, shall be painted or marked upon all such customary weights and measures respectively; and that nothing herein contained shall extend, or be construed to extend, to permit any makers of weights or measures, or any person or persons whomsoever, to make any weight or measure at any time after, except in conformity with the standard weights and measures established under the provisions of this act.

"And be it further enacted, that accurate tables shall be prepared and published, showing the proportions between the weights and measures heretofore in use, as mentioned in such inquisitions, and the weights and measures hereby established; and after the publication of such tables, all future payments to be made shall be regulated according to such tables.

"And whereas the weights and measures by which the rates and duties of the customs and excise, and other his majesty's revenue, have been heretofore collected, are different from the weights and measures of the same denominations directed by this act to be universally used; and whereas the alteration of such weights and measures may, without due care had therein, greatly affect his majesty's revenue, and tend to the diminishing of the same; for the prevention thereof, be it therefore enacted, that, so soon as conveniently may be, accurate tables shall be prepared and published, in order that the several rates and duties of customs and excise, and other his majesty's revenue, may be adjusted and made payable according to the respective quantities of the legal standards directed by this act to be universally used; and that from and after the publication of such tables, the several rates and duties thereafter to be collected by any of the officers of his majesty's customs or excise, or other his majesty's revenue, shall be collected and taken according to the calculations in the tables to be prepared as aforesaid."

Table of the several Standard Measures.—English Long Measure.

Barleycorns.	Inches.	Feet.	Yards.	Poles.	Fur.	Mile.
3 =	1					
36 =	12 =	1				
108 =	36 =	3	1			
594 =	198 =	16½	5½ =	1		
23,768 =	7,920 =	660 =	220 =	40 =	1	
190,080 =	63,360 =	5,280 =	1,760 =	320 =	8 =	1

Also:—

4	Inches . . . . . =	1 Hand
6	Feet . . . . . =	1 Fathom
3	Miles . . . . . =	1 League
60	Geographical miles . . . . . =	1 Degree
69⅓	English miles . . . . . =	1 Degree nearly

360 Degrees, or 25,000 miles, is equal to the circumference of the earth, nearly.

Cloth Measure.

Inches.	Nails.	Quarters.		
2½ =	1			
9 =	4 =			
36 =	16 =	4 =	1	yard
27 =	12 =	3 =	1	ell Flemish
45 =	20 =	5 =	1	ell English
54 =	24 =	6 =	1	ell French

The French standard was formerly the aune, or ell, containing 3 Paris feet, 7 inches, 3 lines, or 1 yard 2-sevenths English; the Paris foot-royal exceeding the English by 68 thousandth-parts. This ell is divided two ways, viz., into halves, thirds, sixths, and twelfths, and into quarters, half-quarters, and sixteenths.

The standard in Holland, Flanders, Sweden, and a good part of Germany—many of which were formerly called the Hans-towns, as Dantzic and Hamburg, and at Geneva, Frankfort, &c.—is likewise the ell; but the ell in all these places differs from the Paris ell. In Holland, it contains one Paris foot eleven lines, or four-sevenths of the Paris ell. The Flanders ell contains two feet one inch five lines and half a line, or seven-twelfths of the Paris ell. The ell of Germany Brabant, &c. is equal to that of Flanders.

The Italian measure is the branchio, brace, or fathom. This obtains in the states of Modena, Venice, Florence, Lucca, Milan, Mantua, Bologna, &c., but is of different lengths. At Venice, it contains one Paris foot eleven inche

three lines, or eight-fifteenths of the Paris ell. At Bologna, Modena, and Mantua, the brace is the same as at Venice. At Lucca, it contains one Paris foot nine inches ten lines, or half a Paris ell. At Florence, it contains one foot nine inches four lines, or forty-nine hundredths of a Paris ell. At Milan, the brace for measuring of silks is one Paris foot seven inches four lines, or four-ninths of a Paris ell; that for woollen cloths is the same with the ell of Holland. Lastly, at Bergamo, the brace is one foot seven inches six lines, or five-ninths of a Paris ell. The usual measure at Naples, however, is the canna, containing six feet ten inches and two lines, or one Paris ell and fifteen-seventeenths.

The Spanish measure is the vara, or yard—in some places called the bara—containing seventeen twenty-fourths of the Paris ell. But measure in Castile and Valencia is the pan, span, or palm, which is used, together with the canna, at Genoa. In Arragon, the vara is equal to a Paris ell and a half, or five feet five inches six lines.

The Portuguese measure is the cavedos, containing two feet eleven lines, or four-sevenths of a Paris ell; and the vara, an hundred and six whereof make an hundred Paris ells.

The Piedmontese measure is the ras, containing one Paris foot nine inches ten lines, or half a Paris ell. In Sicily, their measure, the canna, the same with that of Naples.

The Muscovy measures are the cubic, equal to one Paris foot four inches two lines; and the arcin, two whereof are equal to three cubits.

The Turkish and Levant measures are the picq, containing two feet two inches and two lines, or three-fifths of the Paris ell. The Chinese measure, the cobre, ten whereof are equal to three Paris ells. In Persia, and some parts of the Indies, the gueze, whereof there are two kinds; the royal gueze, called also the *gueze monkelser*, containing two Paris feet ten inches eleven lines, or four-fifths of the Paris ell; and the shorter gueze, called simply *gueze*, only two-thirds of the former. At Goa and Ormuz, the measure is the vara, the same with that of the Portuguese, having been introduced by them. In Pegu, and some other parts of the Indies, the cando, or candi, equal to the ell of Venice. At Goa, and other parts, they use a larger cando, equal to seventeen Dutch ells; exceeding that of Babel and Balsora by $\frac{7}{8}$ per cent., and the vara by $6\frac{1}{2}$. In Siam, they use the ken, short of three Paris feet by one inch. The ken contains two soks, the sok two keubs, the keub twelve nious, or inches, the niou to be equal to eight grains of rice, *i. e.* to about nine lines. At Camboia, they use the haster; in Japan, the tatam; and the span on some of the coasts of Guinea.

Square Measure.

Inches.				
144 =	1 foot			
1,296 =	9 =	1 yard		
39,204 =	$272\frac{1}{4}$ =	$30\frac{1}{4}$ =	1 pole	
1,568,160 =	10,890 =	1,210 =	40 =	1 rood
6,272,640 =	43,560 =	4,840 =	160 =	4 = 1 acre

Also: $5\frac{1}{2}$ yards . . . . . = 1 pole
40 poles . . . . . = 1 rood
4 roods . . . . . = 1 acre

Square, Superficial, or Land Measure.—English square measures are raised from the yard of 36 inches multiplied into itself, and thus producing 1,296 square inches in the square yard; the divisions of this are square feet and inches; and the multiples, poles, roods, and acres. Because the length of a pole is $5\frac{1}{2}$ yards the square of the same contains $30\frac{1}{4}$ square yards. A square mile contains 640 square acres. In measuring fens and woodlands, 18 feet are generally allowed to the pole, and 21 feet in forest-land. A hide of land, frequently mentioned in the earlier part of the English history, contained about 100 arable acres; and five hides were esteemed a knight's fee. At the time of the Norman conquest, there were 243,600 hides in England.

Scotch square or land measure is regulated by the Scotch ell: 36 square ells = 1 fall; 40 falls = 1 rood; 4 roods = 1 acre. The proportion between the Scotch and English acre, supposing the feet in both measures alike, is as 1,369 to 1,089, or nearly as five to four. If the difference of the feet be regarded, the proportion is as 10,000 to 7,869. The length of the chain for measuring land in Scotland is 23 ells, or 74 feet. A husband-land contains six acres of sock and scythe land—that is, of land that may be tilled with a plough, or mown with a scythe; 13 acres of arable land make one ox-gang; and four ox-gangs make a poundland of old extent.

French square measures are regulated by 12 square lines in the inch square, 12 inches in the foot, 22 feet in the perch, and 100 perches in the arpent or acre.

In the following tables, the reader will find enumerated the various general standing measures—long, square, and cubic, now or heretofore in use, with their proportions and reductions.

TABLES OF DIFFERENT MEASURES, ACCORDING TO VARIOUS AUTHORITIES, REDUCED TO ENGLISH MEASUREMENT.

LONG MEASURES.

Table I.—Scripture Long Measure.

		English Ft.	English In.
1 Digit . . . . . =		0	0.912
4 Digits = 1 Palm . . . . . =		0	3.648
3 Palms = 1 Span* . . . . . =		0	10.944
2 Spans = 1 Cubit† . . . . . =		1	9.888
4 Cubits = 1 Fathom . . . . . =		7	3.552
$1\frac{1}{2}$ Fathoms = 1 Reed (Ezekiel's) . . =		10	11.328
$1\frac{1}{3}$ Reeds = 1 Pole (Arabian) . . . =		14	7.104
10 Poles = 1 Scænus, or measuring line =		145	104

* The Orientals used another span, equal to one-fourth of a cubit.

† See Table II.

Table II.—Jewish Long, or Itinerary Measures.

		English Miles.	English Paces.	English Feet.
1 Cubit* . . . . . =		0	0	1.824
400 Cubits . . . = 1 Stadium . . . =		0	145	4.6
5 Stadii . . . = 1 Sab. day's journ. =		0	729	3.0
2 Sab. day's journ. = 1 Eastern mile . =		1	403	1.0
3 Eastern miles . = 1 Parasang . . =		4	153	3.0
8 Parasangs . . = 1 Days' journey =		33	172	4.0

* Dr. Hutton reckons the Hebrew cubit as follow: Eng. feet.
Common Cubit . . . . . = 1.817
Sacred cubit . . . . . = 2.002
Great cubit = 6 common cubits . . . . . = 10.902
The Hebrew foot, according to Dr. Hutton, was equal to 1.212 English foot.

Table III.—Grecian Long Measures.

		English Pa.	English Ft.	English Inches.
1 Dactylus or Digit . . . . . =		0	0	$0.7554\frac{11}{16}$
4 Dactyli . . = 1 Doron, or Dochme, or Palesta =		0	0	$3.0218\frac{3}{4}$
$2\frac{1}{2}$ Palestæ, &c. = 1 Lichas . . . =		0	0	$7.5546\frac{7}{8}$
$1\frac{1}{10}$ Lichas . . = 1 Orthodoron . =		0	0	$8.3101\frac{9}{10}$
$1\frac{1}{11}$ Orthodoron = 1 Spithame . . =		0	0	$9.0656\frac{1}{4}$

		English Pa. Ft. Inches.
$1\frac{1}{3}$ Spithame	= 1 Pous, or foot*	= 0 1 0.0875
$1\frac{1}{8}$ Pous	= 1 Pygme, or cubit	= 0 1 $1.5984\frac{3}{8}$
$1\frac{1}{9}$ Pygme	= 1 Pygon	= 0 1 $3.109\frac{3}{8}$
$1\frac{1}{5}$ Pygon	= 1 Pecus, or larger cubit	= 0 1 6.13125
4 Pecus	= 1 Orgya, or pace	= 0 6 0.525
100 Orgya, or paces	= 1 Stadium, aulus, or furl.	= 100 4 4.5
8 Stadii, &c.	= 1 Million, or mile	= 805 5 0

* The Greek foot is variously estimated; thus:

	Eng. foot.
By Dr. Hutton†	= 1.009
By Folkes, who reckons it equal to $1\frac{1}{24}$ Roman foot	= 1.006 or 1.007
By Cavallo	= 1.007
† Dr. Hutton reckons the Phyleterian foot	= 1.167
† Dr. Hutton reckons the Macedonian foot	= 1.160

N. B. Two sorts of long measures were used in Greece, viz., *the Olympic* and *the Pythic:* the former in Peloponnesus, Attica, Sicily, and the Greek cities in Italy; the latter in Thessaly, Illyria, Phocis, Thrace, and at Marseilles in Gaul.

		Eng. In.
The Olympic foot (properly called *Greek*) contains, according to	Dr. Hutton	12.108
	Folkes	12.072
	Cavallo	12.084
The Pythic foot, (called also *natural foot,*) contains, according to	Dr. Hutton	9.768
	Paucton	9.731

Hence it appears, that
The Olympic stadium is $201\frac{1}{2}$ English yards, nearly.
The Pythic or Delphic stadium, $162\frac{1}{2}$ yards, nearly.
And the other measures in proportion.
The Phyleterian foot is the Pythic cubit, or $1\frac{1}{2}$ Pythic foot.
The Macedonian foot was 13.92 English inches.
The Sicilian foot of Archimedes, 8.76 English inches.

Table IV.—Roman Long Measures.

		English Pa. Ft. In.
6 Scrupula	= 1 Sicilicum	
8 Scrupula	= 1 Duellum	
$1\frac{1}{2}$ Duellum	= 1 Seminaria	
18 Scrupula	= 1 Digitus transversus	= 0 0 $0.725\frac{3}{4}$
$1\frac{1}{3}$ Digiti	= 1 Uncia, or inch	= 0 0 0.967
3 Unciæ	= 1 Palma minor	= 0 0 2.901
4 Palmæ	= 1 Pes, or foot*	= 0 0 11.604
$1\frac{1}{4}$ Pes, or foot	= 1 Palmipes	= 0 1 2.505
$1\frac{1}{5}$ Palmipes	= 1 Cubit	= 0 1 5.406
$1\frac{2}{3}$ Cubits	= 1 Gradus	= 0 2 5.01
2 Gradus	= 1 Passus	= 0 4 10.02
2 Passus	= 1 Decempeda	= 1 4 8.04
125 Passus	= 1 Stadium	= 120 4 4.5
8 Stadii	= 1 Milliare, or Mile †	= 967 0 0

* The length of the Roman foot, in English inches, is stated by various writers as follows:

	Eng. In.
By Bernard	11.640
By Picard and Hutton	11.604
By Folkes	11.592
By Raper (before Titus)	11.640
By the same (after Titus)	11.580
By Shuckburgh, from rules	11.6064
By the same, from buildings	11.6172
By the same, from a tomb-stone	11.6352

Hence 11.6 Eng. in. seem to be a medium; and, therefore, the Roman mile = 1611 English yds., being 149 yds. less than the English mile.

Its proportion to the English foot is thus stated:—

By Bernard	.970	By Raper	Before Titus .970; After Titus .965
By Picard and Greaves	.976	By Shuckburgh	From Rules .9672; From Build. .9681; From a Stone. 9696
By Folkes	.966, .967	By Dr. Hutton	.967

† The Roman mile of Pliny (according to Cavallo) contained 4840.5 English feet; and that of Strabo 4903.

Table V.—Ancient Long Measures, according to Dr. Hutton.

	Eng. Feet.
Arabian foot	= 1.095
Babylonian foot	= 1.144 or 1.135
Drusian foot	= 1.090
Egyptian foot	= 1.421
——— stadium	= 7.308
Natural foot	= .814
Ptolemaic = the Greek foot (see Table III.)	
Sicilian foot of Archimedes	= .730

Table VI.—Scottish Long Measures.

	Eng. Inches.
An Ell	= 37.2
A Fall	= 223.2
A Furlong	= 8928.
A Mile	= 71424.
A Link	= 8.928
A Chain, or Short Rood	= 89.28
A Long Rood	= 1339.2

Table VII.—French Long Measures, before the First Revolution.

	Eng. Inches.
A Point	= .0148025, or nearly $\frac{2}{135}$.
A Line	= .088815, or nearly $\frac{8}{90}$.
An Inch, or Pouce	= 1.06578, or, $\frac{1}{938}\frac{1}{28}$, or $\frac{81}{76}$.
A Foot	= 12.78933
An Ell, or Aune*	= 46.8947, or 44 French In.; or, according to Vega, 43.9
A Sonde	= 63.9967, or 5 French feet, about $\frac{8}{9}$ English fathom.
A Toise, or Fathom	= 76.7360, or 6 French feet.†
A Perche	= 230.2080, or 18 French feet.
A Perche, mesure royale	= 22 French feet.
A League	= 2282 toises, or $\frac{1}{25}$ of a degree

* The aune, or ell, of Paris, varies, being for silk stuffs 527.5 lines, or $46\frac{17}{20}$ English inches; for woollens, 526.4 French lines, or $46\frac{3}{4}$ English inches; for linens, 524 French lines, or $46\frac{11}{20}$ English inches; and it varies still more in other parts of France.

† Formerly 76.71, *Phil. Trans.* for 1742.

Table VIII.—French Long Measures, according to the Present System.

		Eng. Inches.
Millimetre	=	.03937
Centimetre	=	.39371
Decimetre	=	3.93710
Metre	=	39.37100, or 3.281 feet, or 1.09364 yards, or nearly 1 yard $1\frac{1}{2}$ nail, or 443.2959 French lines, or .513074 toise.
Decametre	=	393.71000, or 10 yards, 2 feet, 9.7 inches.
Hecatometre	=	3937.10000, or 100 yards, 1 foot, 1 inch.
Chiliometre	=	39371.00000, or 4 furlongs, 213 yards, 1 foot 10.2 inches: so that 8 chiliometres are nearly 5 miles.
Myriometre	=	393710.0000, or 6 miles, 1 furlong, 136 yards, 0 feet, 6 inches.

N.B. An inch is .0354 metres; 2441 inches 62 metres; 1000 feet nearly 305 metres.

In order to express decimal proportions in this new system, the following terms have been adopted. The term *Deca*

prefixed denotes 10 times; *Heca*, 100 times; *Chilio*, 1000 times; and *Myrio*, 10,000 times. On the other hand, *Deci* expresses the tenth part; *Centi*, the hundredth part; and *Milli*, the thousandth part; so that *Decametre* signifies 10 metres; and a *Decimetre*, the 10th part of a metre, &c. &c. The *Metre* is the element of long measures; *Are*, that of square measures; *Stere*, that of solid measures; the *Litre* is the element of all measures of capacity; and the *Gramme*, which is the weight of a cubic centimetre of distilled water, is the element for all weights.

Table IX.—Proportions of several Long Measures to each other, by M. Picard.

	Parts.
The Rhinland, or Leyden foot, (12 whereof make the Rhinland perch) supposed	696
The English foot	675½
The Paris foot	720
The Amsterdam foot, from that of Leyden, by Snellius	629
The Danish foot (two whereof make the Danish ell)	701 8/10
The Swedish foot	658¼
The Brussels foot	609 3/5
The Dantzic foot, from Hevelius's Selenographia	636
The Lyons foot, by M. Auzout	757⅔
The Bologna foot, by the same	843
The braccio of Florence, by the same, and father Mersenne	1290
The palm of the architects at Rome, according to the observations of Messrs. Picard and Auzout	494¼
The Roman foot in the Capitol, examined by Messrs. Picard and Auzout	653 or 653½
The same from the Greek foot	652
From the vineyard Mattei	657½
From the palm	658¼
From the pavement of the Pantheon, supposed to contain 10 Roman feet	653
From a slip of marble in the same pavement, supposed to contain 3 Roman feet	650
From the pyramid of Cestius, supposed to contain 95 Roman feet	653½
From the diameters of the columns in the arch of Septimius Severus	653⅓
From a slip of porphyry in the pavement of the Pantheon	653⅓

Table X.—Proportions of the Long Measures of several Nations to the English Foot, taken from Greaves, Auzout, Picard, and Eisenchmid.

The English standard foot being divided into 1000 equal parts, the other measures will have the proportions to it which follow:—

	Parts.	Inches.
English foot	1000	12.
Paris foot	1068	12.816
Venetian foot	1162	13.944
Rhinland foot	1033	12.396
Strasburg foot	952	11.424
Nuremberg foot	1000	12.
Dantzic foot	944	11.328
Danish foot	1042	12.504
Swedish foot	977¾	11.733
Derahor cubit of Cairo	1824	21.888
Persian arish	3197	38.364
Greater Turkish pike	2200	26.4
Lesser Turkish pike	2131	25.572
Braccio at Florence	1913	22.956
Braccio for woollen at Sienna	1242	14.904
Braccio for linen at Sienna	1974	23.688
Canna at Naples	6880	82.56
Vera, at Almeira and Gibraltar	2760	33.12
Palmo di Archtetti at Rome	7320	87.84
Fanna di Archtetti	7320	87.84
Palmo di braccio di mercantia	695½	8.346
Genoa palm	815	9.78
Bolognian foot	1250	15.
Antwerp ell	2283	27.396
Amsterdam ell	2268	27.216
Leyden ell	2260	27.12
Paris draper's ell	3929	47.148
Paris mercer's ell	3937	47.244

Table XI.—Modern Long Measures of several Countries compared with English Feet.

Compiled by Dr. Young, from various Authorities.

	Eng. Ft.	Authorities.
Altdorf, foot	.775	Dr. Hutton
Amsterdam, foot	.927	ditto
	.930	Cavallo
	.931	Howard
Amsterdam, ell	2.233	Cavallo
Ancona, foot	1.282	Dr. Hutton
Antwerp, foot	.940	ditto
Aquileia, foot	1.128	ditto
Arles, foot	.888	ditto
Augsburg, foot	.972	ditto
Avignon=Arles. *See* Arles.		
Barcelona, foot	.992	ditto
Basle, foot	.994	ditto
Bavarian, foot	.968	Beigal. *See* MUNICH.
Bergamo, foot	1.431	Dr. Hutton
Berlin, foot	.992	ditto
Berne, foot	.962	Howard
Besançon, foot	1.015	Dr. Hutton
Bologna, foot	1.244	ditto
	1.250	Cavallo
Bourg en Bresse, foot	1.030	Dr. Hutton
Brabant, ell, in Germany	2.268	Vega
Bremen, foot	.955	Dr. Hutton
Brescia, foot	1.560	ditto
Brescian, braccio	2.092	Cavallo
Breslau, foot	1.125	Dr. Hutton
Bruges, foot	.749	ditto
Brussels, foot	.902	ditto
	.954	Vega
Brussels, greater ell	2.278	ditto
Brussels, lesser ell	2.245	ditto
Castilian, vara	2.746	Cavallo
Chambery, foot	1.107	Dr. Hutton
China, mathematical foot	1.127	ditto
China, imperial foot	1.051	ditto
	1.050	Cavallo
Chinese, li	606.	ditto
Cologne, foot	.903	Dr. Hutton
Constantinople, foot	2.195	ditto
	1.165	ditto
Copenhagen, foot	1.049	ditto
Cracau, foot	1.169	ditto
Cracau, greater ell	2.024	Vega

	Eng. Ft.	Authorities.
Cracau, smaller ell	1.855	Vega
Dantzic, foot	.923	Dr. Hutton
Dauphiné, foot	1.119	ditto
Delft, foot	.547	ditto
Denmark, foot	1.047	ditto
Dijon, foot	1.030	ditto
Dordrecht, foot	.771	ditto
Dresden, foot	.929	Wolfe, Ph. Trans. 1769.
Dresden ell = 2 feet	1.857	Vega [Vega.
Ferrara, foot	1.317	Dr. Hutton
Florence, foot	.995	ditto
Florence, braccio	1.900	Cavallo
	1.910	ditto
Franche Comté, foot	1.172	Dr. Hutton
Frankfort = Hamburg		ditto
Genoa, palm	.812	ditto
	.800	Cavallo
	.817	ditto
Genoa, canna	7.300	ditto
Geneva, foot	1.919	Dr. Hutton
Grenoble = Dauphiné		ditto
Haarlem, foot	.937	ditto
Halle, foot	.977	ditto
Hamburg, foot	.933	ditto
Heidelberg, foot	.903	ditto
Inspruck, foot	1.101	ditto
Leghorn, foot	.992	ditto
Leipzig, foot	1.034	ditto
Leipzig, ell	1.833	Dr. Hutton, Journ. R. I.
Leyden, foot	1.023	ditto
Liege, foot	.944	ditto
Lisbon, foot	.952	ditto
Lucca, braccio	1.958	Cavallo
Lyons = Dauphiné		
Madrid, foot	.915	Dr. Hutton
	.918	Howard
Madrid, vara	3.263	Cavallo
Maestricht, foot	.916	Dr. Hutton
Malta, palm	.915	ditto
Mantua, brasso	1.521	ditto
Mantuan, braccio = Brescian		Cavallo
Marseilles, foot	.814	Dr. Hutton
Mechlin, foot,	.753	ditto
Mentz, foot	.988	ditto
Milan, decimal foot	.855	ditto
Milan, aliprand foot	1.426	ditto
Milanese, braccio	1.725	Cavallo
Modena, foot	2.081	Dr. Hutton
Monaco, foot	.771	ditto
Montpelier, pan	.777	ditto
Moravian, foot	.971	Vega
Moravian, ell	2.594	ditto
Moscow, foot	.928	Dr. Hutton
Munich, foot	.947	ditto
Naples, palm	.861	ditto
	.859	Cavallo
Naples, canna	6.908	ditto
Nuremberg, town foot	.996	Hutton
	.997	Vega
Nuremberg, country foot	.907	Dr. Hutton
Nuremberg, artillery foot	.961	Vega
Nuremberg, ell	2.166	ditto
Padua, foot	1.406	Dr. Hutton
Palermo, foot	.747	ditto
Paris, foot	1.066	ditto

	Eng. Ft.	Authorities.
Paris metre	3.281	Dr. Young
Parma, foot	1.869	Dr. Hutton
Parmesan, braccio	2.242	Cavallo
Pavia, foot	1.540	Dr. Hutton
Placentia = Parma		Cavallo
Prague, foot	.987	Dr. Hutton
	.972	Vega
Prague, ell	1.948	ditto
Provence = Marseilles		Dr. Hutton
Rhinland, foot	1.023	ditto
	1.030	Vega. Eytelwein
Riga = Hamburg		
Rome, palm	.733	Dr. Hutton
Rome, foot	.966	Folkes.
Rome, ditto, $\frac{1}{16}$ foot	.0604	ditto
Rome, oncia, $\frac{1}{12}$ foot	.0805	ditto
Rome, Palmo	.2515	ditto
Rome, palmo di architettura	.7325	ditto
Rome, canna di architettura	7.325	ditto
Rome, staiolo	4.212	ditto
Rome, canna dei mercanti	6.5365	ditto, 8 palms
Rome, braccio dei mercanti	2.7876	ditto, 4 palms
	2.856	Cavallo
Rome, braccio di tessitor di tela	2.0868	Folkes
Rome, braccio di architettura	2.561	Cavallo
Rouen = Paris		Dr. Hutton
Russian, archine	2.3625	Cavallo
Russian, arschin	2.3333	Ph. M. XIX.
Russian, verschock, $\frac{1}{16}$ arschin	.1458	
Savoy = Chambery		Dr. Hutton
Seville = Barcelona		ditto
Seville, vara	2.760	Cavallo
Sienna, foot	1.239	Dr. Hutton
Stettin, foot	1.224	ditto
Stockholm, foot	1.073	ditto
Stockholm, foot	.974	Celsius Ph. Tr.)
Strasburg, town foot	.956	Dr. Hutton
Strasburg, country foot	.969	ditto
Toledo = Madrid		Dr. Hutton
Trent, foot	1.201	ditto
Trieste, ell for woollens	2.220	ditto
Trieste, ell for silk	2.107	ditto
Turin, foot	1.676	ditto
	1.681	Cavallo
Turin, ras	1.958	ditto
Turin, trabuco	10.085	ditto
Tyrol, foot	1.096	Vega
Tyrol, ell	2.639	ditto
Valladolid, foot	.908	Dr. Hutton
Venice, foot	1.137	ditto
	1.140	Bernard. Howard. Vega
	1.167	Cavallo
Venice, braccio of silk	2.108	ditto
Venice, ell	2.089	Vega
Venice, braccio of cloth	2.250	Cavallo
Verona, foot	1.117	Dr. Hutton
Vicenza, foot	1.136	ditto
Vienna, foot	1.036	ditto
	1.037	Howard. Cavallo. Vega
Vienna, ell	2.557	Vega
Vienna, post mile	24888.	ditto

	Eng. Ft.	Authorities.
Vienne in Dauphiné foot	1.058	Dr. Hutton
Ulm, foot	.826	ditto
Urbino, foot	1.162	ditto
Utrecht, foot	.741	ditto
Warsaw, foot	1.169	ditto
Wesel = Dordrecht		ditto
Zurich, foot	.979	ditto
	.984	Ph. M. VIII. 289.

Table XII.—A Comparison of the Foot, and other measures of Length, in different countries.

		Number of each equal to 100 English Feet.	Length of a single Measure of each sort. E. Inches.
Aix la Chapelle	Feet	105.18	11.41
Amsterdam	ditto	107.62	11.15
Anspach	ditto	102.38	11.72
Ancona	Feet	78.02	15.38
Antwerp	ditto	106.76	11.24
Aquileia	ditto	88.69	13.53
Augsburg	ditto	103.	11.65
Basil	ditto	102.22	11.74
Bavaria	ditto	105.08	11.42
Bergamo	ditto	69.89	17.17
Berlin	ditto	98.44	12.19
Berne	ditto	103.98	11.54
Bologna	ditto	80.05	14.99
Bremen	ditto	105.45	11.38
Brescia	Bracci	64.10	18.72
Breslaw	Feet	107.24	11.19
Brunswick	ditto	106.85	11.23
Brussels	ditto	104.80	11.45
Cadiz	(See Spain)		
Cagliari	Palmi	150.52	7.97
Calenberg	Feet	104.34	11.50
Carrara	Palmi	125.	9.60
Castille	(See Spain)		
Chambery	Feet	90.36	13.28
China	Mathematical feet	91.46	13.12
	Builders' ditto	94.41	12.71
	Tradesmen's ditto	90.08	13.32
	Land Surveyor's ditto	95.39	12.58
Cleves	Feet	103.18	11.63
Cologne	ditto	110.80	10.83
Copenhagen	Legal Feet	97.17	12.35
	Fathoms	16.20	74.10
	Ruthes	9.71	123.50
Cracow	Feet	85.53	14.03
Dantzic	ditto	106.28	11.29
	Ruthes	7.08	169.35
Dordrecht	Feet	84.74	14.16
Dresden	ditto	107.62	11.14
Embden	ditto	102.92	11.66
England	ditto	100.	12.
	Yards	33.33	36.
	Poles	6.06	198.
Ferrara	Feet	75.95	15.80
	Pertichi	11.11	108.
Florence	Builders' Bracci	55.55	21.60
France	Pieds du Roi	93.89	12.78
	Toises	15.65	76.68
	Metres	30.48	39.37
Francfort	Feet	106.48	11.27
Geneva	ditto	62.50	19.20
Genoa	Palmi	123.45	9.72
Gottingen	Feet	104.80	11.45
Gotha	ditto	106.	11.32
Groningen	ditto	104.44	11.49
	ditto	106.28	11.29
Hamburg	Rhinland ditto	97.17	12.35
	Clafters	17.71	67.74
	Masch Ruthes	7.59	158.06
	Geest ditto	6.64	180.64
	Rhinland ditto	8.10	148.20
Hanover	Feet	104.80	11.45
	Ruthes	6.50	183.20
Haerlem	Feet	106.67	11.25
Heidelberg	ditto	109.48	10.96
Hildesheim	ditto	108.60	11.05
Holstein	(See Copenhagen)		
Inspruck	Feet	96.	12.50
Konigsburg	ditto	99.09	12.11
Leghorn	(See Florence)		
Leipsic	Common feet	108.01	11.11
	Builders' ditto	107.81	11.13
Leyden	ditto	97.24	12.34
Liege	ditto	106.	11.32
Lindau	Common feet	105.26	11.40
	Long ditto	96.77	12.40
Lisbon	Feet	92.78	12.96
	Palmi	139.17	8.64
Lorraine	Feet	106.20	11.30
Lubec	ditto	104.80	11.45
	Ruthes	6.55	183.20
Luneburg	Feet	104.80	11.45
Madrid	(See Spain)		
Magdeburg	Feet	107.52	11.16
Malta	ditto	107.43	11.17
Manheim	ditto	105.39	11.41
Mantua	Bracci	65.75	18.25
Maestricht	Feet	108.60	11.05
Mecklenberg	(See Hanover)		
Mentz	Feet	101.26	11.85
Middleburg	ditto	101.61	11.81
Milan	ditto	76.82	15.62
	Bracci	62.34	19.25
Monaco	Feet	129.73	9.25
Moscow	ditto	91.12	13.17
Naples	Palmi	115.62	10.38
Neufchatel	Feet	101.61	11.81
Nuremberg	ditto	100.34	11.96
Oldenburg	ditto	103.	11.65
Osnaburg	ditto	109.09	11.
Padua	ditto	86.15	13.93
Palermo	Palmi	125.93	9.53
Paris	(See France)		
Parma	Surveyors' Bracci	56.23	21.34
Pavia	ditto	65.57	18.30
Persia	Arish	31.36	38.27
Pomerania	Feet	104.34	11.50
Portugal	(See Lisbon)		
Prague	Feet	101.	11.88
Ratisbon	(See Bavaria)		
Ratzburgh	Feet	104.80	11.45
Revel	ditto	113.96	10.53
Reggio	Bracci	57.55	20.85
Rhinland	Feet	97.17	12.35
Riga	ditto	111.21	10.79

		Number of each equal to 100 English Feet.	Length of a single Measure of each sort. E. Inches.
Rimini	Bracci	56.10	21.39
Rome	Feet	103.45	11.60
	Builders' Canne	13.65	87.92
	Palmi	136.49	8.79
Rostock	Feet	105.45	11.38
Rotterdam	(See Rhinland)		
Russia	Arsheens	42.86	28.
	Sashès	14.28	84.
	Feet	87.27	13.75
Sardinia	Palmi	122.70	9.78
Savoy	(See Chambery)		
Sienna	Feet	80.75	14.86
Sicily	(See Palermo)		
Silesia	Ruthes	7.06	170.
Spain	Feet	107.91	11.12
	Toesas	17.98	66.72
	Palmos	143.88	8.34
Stade	Feet	104.80	11.45
Stettin	ditto	107.91	11.12
Stockholm	(See Sweden)		
Strasburg	Feet	105.35	11.39
	Land ditto	103.28	11.62
	(See also France)		
Stutgard	(See Wurtemberg)		
Sweden	Feet	102.66	11.69
	Fathoms	17.11	70.14
	Rods	6.43	187.04
Trent	Feet	83.28	14.41
Turin	ditto	94.34	12.72
Ulm	ditto	105.35	11.39
Utrecht	ditto	111.82	10.74
Venice	ditto	87.72	13.40
Verona	ditto	89.55	13.68
Vicenza	ditto	88.04	13.63
Vienna	ditto	96.39	12.45
Warsaw	ditto	85.53	14.03
Wismar	ditto	103.63	11.58
Wurtemberg	ditto	104.80	11.45
Zeil	(See Hanover)		
Ziriczee	Feet	98.28	12.21
	ditto	101.60	11.81
Zurich	Ruthes	10.16	118.10
	Fathoms	16.32	73.50

Table XIII.—A Comparison of the Itinerary Measures of different Countries.

		Number of each equal to 100 English Miles.	Length of a single Measure of each sort. Eng. Yds.
Arabia	Miles	81.93	2148
Bohemia	ditto	17.36	10137
Brabant	ditto	28.93	6082
Burgundy	ditto	28.46	6183
China	Lis	279.80	629
Denmark	Miles	21.35	8244
England	ditto	100.	1760
	ditto Geographical	86.91	2625
Flanders	Miles	25.62	6869
France	Leagues, Astronomical	36.21	4860
	ditto, Marine	28.97	6075
	ditto, legal, 2000 Toises	41.28	4263
Germany	Miles, Geographical	21.72	8101
	ditto, Long	17.38	10126
	ditto, Short	25.66	6859
Hamburg	Miles	21.35	8244
Hanover	ditto	15.23	11559
Hesse	ditto	16.68	10547
Holland	ditto	27.52	6395
Hungary	ditto	19.31	9113
Ireland	ditto	57.93	3038
Italy	ditto	86.91	2025
Lithuania	ditto	18.	9781
Oldenburg	ditto	16.26	10820
Poland	Miles, Short	28.97	6075
	ditto, Long	21.72	8101
Portugal	Legoas	26.03	6760
Prussia	Miles	20.78	8468
Rome	Ancient mile of 8 stadia	109.18	1612
	Modern Miles	86.91	2025
Russia	Versts	150.81	1167
Saxony	Miles	17.76	9905
Scotland	ditto	88.70	1984
Silesia	ditto	27.67	7083
Spain	Leguras, common, of 8,000 Varas	23.73	7416
	ditto, legal, of 5000 Varas	37.97	4635
Swabia	Miles	17.38	10126
Sweden	ditto	15.04	11700
Switzerland	ditto	19.23	9153
Turkey	Berries	96.38	1826
Westphalia	Miles	14.56	12151

SUPERFICIAL, or SQUARE MEASURES.

Table XIV.—Ancient Greek superficial Measures.

Olympic Land Measure.

36 Olympic square feet = 1 Hexapodon.
6 Hexapoda = 1 Hemihectos.
2 Hemihecti = 1 Hectos or Modius.
6 Modii = 1 Medimnus or Jugerum.

Hence it appears, that the Olympic jugerum was equal to 103 English perches, or nearly five-eighths of an acre.

Pythic Land Measure.

1666⅔ Square cubits = 1 Hemihectos.
2 Hemihecti = 1 Modius.
6 Modii = 1 Medimnus or Jugerum.

Hence the Pythic jugerum appears to have been equal to 109 English perches, or nearly $\frac{11}{16}$ths of an acre.

N.B. The plethron, or acre, is said by some to contain 1444, by others 10,000 square feet; and aroura, the half of the plethron. The aroura of the Egyptians was the square of 100 cubits.

Table XV.—Ancient Roman Land Measures.

100 Square Roman feet = 1 Scrupulum of land.
4 Scrupula = 1 Sextulus.
1⅕ Sextulus = 1 Actus*
6 Sextuli, or 5 Actus = 1 Uncia of land.
6 Unciæ = 1 Square Actus.
2 Square Actus = 1 Jugerum.†
2 Jugera = 1 Heredium.
100 Heredia = 1 Centuria.

* The actus was a slip of ground four Roman feet broad, and 120 long.

† The jugerum, or acre, was considered as integer, and divided, like the libra, or as, in the following manner:

		Unciæ.	Jugerum contained Roman. Sq. Ft.	Scrup.	English. Rds.	Pol.	Sq. Ft.
1	As	= 12 =	28800	288 =	2	18	250.05
$\frac{11}{12}$	Deunx	= 11 =	26400	264 =	2	10	183.85
$\frac{5}{6}$	Dextans	= 10 =	24000	240 =	2	2	117.64
$\frac{3}{4}$	Dodrans	= 9 =	21600	216 =	1	34	51.42
$\frac{2}{3}$	Bes	= 8 =	19200	195 =	1	25	257.46
$\frac{7}{12}$	Septunx	= 7 =	16800	168 =	1	17	191.25
$\frac{1}{2}$	Semis	= 6 =	14400	144 =	1	9	125.03
$\frac{5}{12}$	Quincunx	= 5 =	12000	120 =	1	1	58.82
$\frac{1}{3}$	Triens	= 4 =	9600	96 =	0	32	264.85
$\frac{1}{4}$	Quadrans	= 3 =	7200	72 =	0	24	198.64
$\frac{1}{6}$	Sextans	= 2 =	4800	48 =	0	16	132.43
$\frac{1}{12}$	Uncia	= 1 =	2400	24 =	0	8	66.21

N. B. If we take the Roman foot at 11.6 English inches (*See* TABLE V.) the Roman jugerum was = 5980 English square yards, or 1 acre 37½ perches.

Table XVI.—English Square Measures.

144	Inches	= 1 Foot.
9	Feet	= 1 Yard.
2½	Yards	= 1 Pace.
10.89	Paces	= 1 Pole.
40	Poles	= 1 Rood.
4	Roods	= 1 Acre.

N.B. English square or superficial measures are raised from the yard of 36 inches, multiplied into itself; and this producing 1296 square inches in the square yard, the divisions of this are square feet and inches; and the multiples, poles, roods, and acres, as in the Table. The Scottish acre is 55353.6 square feet English, or 1.27 English acres.

Measures used by different Artificers.

144	Square inches	= 1 Square foot.
9	Square feet	= 1 Square yard.
63	Square feet=7 Sq. yards .	= 1 Rood.
100	Square feet	= 1 Square of work.
272¼	Square feet=30¼ Sq. yards	= 1 Rod, perch, or square pole.

Table XVII.—French Square Measures before the First Revolution.

A Square Inch . . . . =	1.13582 English sq. inches.
An Arpent . . . . . =	100 Square perches, French, about $\frac{5}{6}$ acre English, used near Paris.
An Arpent, mesure royale* =	about 1¼ English acre.

* The perch (*See* TABLE VIII,) which determines the measure of the acre, varies in different parts of the country: but the arpent of woodland is everywhere the same, the perch being 22 feet long; and this arpent contains 48,400 French square feet, or 6108 English square yards, or one acre, one rood, one perch. The arpent for cultivated land, in the vicinity of Paris, contains 900 square toises, or 4088 English yards; so that 43 such arpents are equal to 38 English acres nearly.

Table XVIII.—French Square Measures, according to the present System.

Are, a square decametre . =	3.95 English perches, or 119.6046 Square yards.
Decare . . . . . =	1196.0460 Square yards.
Hecatare . . . . . =	11960.4600 Square yards, or 2 acres, 1 rood, 35.4 perches.

Table XIX.—Contents of a Square Foot of different Countries.

	Eng. Square Inches.
A Square Foot of Amsterdam contains	124.32
Antwerp	126.34
Berlin	148.59
Berne	133.23
Bologna	224.70
Bremen	129.50
Denmark or Rhinland . . .	152.52
Danzic	127.46
Dresden	124.10
England	144.00
France	163.32
Hamburg.	127.46
Hanover	131.10
Konigsberg	146.65
Leipsic	123.43
Lisbon	167.96
Milan	234.98
Nuremberg	134.04
Osnaburg	121.00
Rome	134.56
Spain	123.65
Sweden	136.65
Turin	161.80
Venice	187.13
Vienna	155.00
Zurich	139.42
A French Square Metre	1505.01

Cubical Measures, or Measures of Capacity, for Liquids.—The English measures were originally raised from troy weight: it being enacted by several statutes, that eight pounds troy of wheat, gathered from the middle of the ear, and well dried, should weigh a gallon of wine measure, the divisions and multiples whereof were to form the other measures; at the same time it was also ordered, that there should be but one liquid measure in the kingdom; yet custom has prevailed, and there having been introduced a new weight, viz., the avoirdupois, we have now a second standard gallon adjusted thereto; and therefore exceeding the former in the proportion of the avoirdupois weight to troy weight. From this latter standard are raised two several measures, the one for ale, the other for beer. The sealed gallon at Guildhall, which is the standard for wines, spirits, oils, &c. was supposed to contain 231 cubic inches; but by actual experiment, made in 1688, before the lord mayor and the commissioners of excise, it was found to contain only 224 cubic inches, it was, however, agreed to continue the common supposed contents of 231 cubic inches; so that all computations stood on their own footing. Hence as 12 is to 231, so is $14\frac{12}{20}$ to $281\frac{1}{2}$, the cubic inches in the ale gallon: but in effect the ale quart contained $70\frac{1}{2}$ cubic inches, on which principle the ale and beer gallon will be 282 cubic inches. The barrel of ale in London is 32 gallons, and the barrel of beer 36 gallons. In all other places of England, the barrel, both for ale and beer, was wont to be 34 gallons.

Scotch liquid measure is founded on the pint. The Scotch pint was formerly regulated by a standard jug of cast metal, the custody of which was committed to the borough of Stirling. This jug was supposed to contain 105 cubic inches; and though, after several careful trials, it has been found to contain only about $103\frac{1}{2}$ inches, yet in compliance with established custom, founded on that opinion, the pint stoups are still regulated to contain 105 inches, and the customary ale

measures are about $\frac{1}{16}$ above that standard. It was enacted by James I. of Scotland, that the pint should contain 41 ounces trone weight of the clear water of Tay, and by James VI. that it should contain 55 Scots troy ounces of the clear water of Leith. This affords another method of regulating the pint, and also ascertaining the ancient standard of the trone weight. As the water of Tay and Leith is alike, the trone weight must have been to the Scots troy weight, as 55 to 41, and therefore the pound trone must have contained about $21\frac{1}{2}$ ounces Scots, troy.

4 Gills	=	1 Mutchkin.
2 Mutchkins	=	1 Chopin
2 Chopins	=	1 Pint
2 Pints	=	1 Quart
4 Quarts	=	1 Gallon.

The Scotch quart contains 210 inches, and is therefore about $\frac{1}{10}$ less than the English wine gallon, and about $\frac{1}{4}$ less than the ale gallon.

As to the liquid measures of foreign nations, it is to be observed, that their several vessels for wine, vinegar, &c. have also various denominations, according to their different sizes and the places wherein they are used. The woeders of Germany, for holding Rhenish and Moselle wines, are different in their guages; some containing 14 aumes of Amsterdam measure, and others more or less. The aume is reckoned at Amsterdam for 8 steckans, or 20 verges, or for $\frac{1}{6}$ of a tun of 2 pipes, or 4 barrels of French or Bordeaux, which $\frac{1}{6}$ at this latter place is called *tierçon*, because three of them make a pipe, or two barrels, and six the said tun. The steckan is 16 mingles, or 32 pints; and the verge is, in respect of the said Rhenish and Moselle, and some other sorts of wine, 6 mingles, but in measuring brandy it consists of $6\frac{1}{6}$ mingles. The aume is divided into 4 anckers, and the ancker into 2 steckans, or 32 mingles. The ancker is taken sometimes for $\frac{1}{24}$ of a tun, or 4 barrels; on which footing the Bordeaux barrel ought to contain at Amsterdam (when the cask is made according to the just guage,) $12\frac{1}{2}$ steckans, or 200 mingles, wine and lees; or 12 steckans, or 192 mingles, racked wine; so that the Bordeaux tun of wine contains 50 steckans, or 800 mingles, wine and lees; and 48 steckans, or 768 mingles, of pure wine. The barrels, or poinçons, of Nantes, and other places on the river Loire, contain only 12 steckans, Amsterdam measure. The wine tun of Rochelle, Cogniac, Charente, and the Isle of Rhé, differs very little from the tun of Bordeaux, and consequently from the barrels and pipes. A tun of wine of Chalosse, Bayonne, and the neighbouring places, is reckoned 60 steckans, and the barrel 15, Amsterdam measure.

The old muid of Paris contains 150 quarts or 300 pints, wine and lees; or 280 pints clear wine; of which muids three make a tun.

The butts, or pipes, from Cadiz, Malaga, Alicant, Benecarlo, Saloe, and Mataro, and from the Canaries, Lisbon, Oporto, and Fayal, are very different in their guages, though in affreightments they are all reckoned two to the tun.

Vinegar is measured in the same manner as wine, but the measures for brandies are different, these spirits, from France, Spain, Portugal, &c., are generally shipped in large casks, called pipes, butts, and pieces, according to the places from whence they are imported, &c. In France, brandy is shipped in casks called pieces at Bordeaux, and pipes at Rochelle, Cogniac, the Isle of Rhé, and other neighbouring places, which contain some more and some less, even from 60 to 90 Amsterdam verges or veertels, according to the capacity of the vessel, and the places they come from.

Dry Measure.

Pints.							
8	=	1 Gallon					
16	=	2	=	1 Peck			
64	=	8	=	4	=	1 Bushel	
256	=	32	=	16	=	4	= 1 Coomb
512	=	64	=	32	=	8	= 2 = 1 Quarter
2560	=	320	=	160	=	40	= 10 = 5 = 1 Wey
5120	=	640	=	320	=	80	= 20 = 10 = 2 = 1 Last

$268\frac{4}{5}$ Cubic Inches = 1 Gallon

36 Bushels = 1 Chaldron of Coals.

Measure of Capacity for things Dry, was the Winchester gallon heretofore; as for corn, salt, coal, and other dry goods, in England. The gallon contains $272\frac{1}{4}$ cubic inches. The bushel 8 gallons, or 2178 inches. A cylindrical vessel, $18\frac{1}{2}$ inches diameter, and 8 inches deep, is appointed to be used as a bushel in levying the malt tax. A vessel of these dimensions is rather less than the Winchester bushel of 8 gallons, for it contains only 2150 inches, though probably there was no difference intended. The denominations of dry measure commonly used, are given in the first of the subjoined tables. Four quarters of corn make a chaldron, five quarters make a wey or load, and ten quarters make a tun. In measuring seacoal, five pecks make a bushel, nine bushels make a quarter or vatt, four quarters make a chaldron, and twenty-one chaldrons make a score.

40 feet hewn timber make a load.
50 feet unhewn timber make a load.
32 gallons make a herring barrel.
42 gallons make a salmon barrel.
1 cwt. gunpowder makes a barrel.
256 lbs. soap make a barrel.
10 doz. candles make a barrel.
12 barrels make a last.

Scotch dry measure. There was formerly only one measure of capacity in Scotland; and some commodities were heaped, others straiked, or measured exactly to the capacity of the standard. The method of heaping was afterwards forbidden as unequal, and a larger measure appointed for such commodities as that custom had been extended to. The wheat firlot, used also for rye, pease, beans, salt, and grass seeds, contains 21 pints 1 mutchkin, measured by the Stirling jug. The barley firlot, used also for oats, fruit, and potatoes, contains 31 pints. A different method of regulating the firlot was appointed from a cylindrical vessel. The diameter for both measures was fixed at $19\frac{1}{6}$ inches, the depth $7\frac{1}{2}$ inches for the wheat firlot, and $13\frac{1}{2}$ for the barley firlot. A standard constructed by these measures is rather less than when regulated by the pint; and as it is difficult to make vessels exactly cylindrical the regulation by the pint has prevailed, and the other method gone into disuse.

If the Stirling jug contains $103\frac{1}{2}$ inches, the wheat firlot will contain 2109 inches, which is more than two per cent. larger than the legal malt bushel of England, and about one per cent. larger than the Winchester bushel; and the barley firlot will contain 3208 inches. The barley boll is nearly equal to six legal malt bushels. In Stirlingshire, 17 pecks are reckoned to the boll; in Inverness-shire, 18 pecks; in Ayrshire, the boll is the same as the English quarter. And the firlots in many places are larger than the Linlithgow standard.

French dry measure, are the litron, bushel, minot, mine, septier, muid, and tun. The litron is divided into two demilitrons, and four quarter litrons, and contains 36 cubic inches of Paris. By ordonnance, the litron is to be three inches and a half high, and three inches ten lines broad. The litron

for salt is larger, and is divided into two halves, four quarters, eight demi-quarters, and 16 measurettes. The French bushel is different in different jurisdictions. At Paris it is divided into demi-bushels, each demi-bushel into two quarters, the quart into two half-quarts, and the half-quart into two litrons, so that the bushel contains 16 litrons. By ordonnance the Paris bushel is to be 8 inches 2½ lines high, and 10 inches broad, or in diameter within side. The minot consists of 3 bushels, the mine of 2 minots or 6 bushels, the septier of 2 mines or 12 bushels, and the muid of 12 septiers, or 144 bushels. The bushel of oats is estimated double that of any other grain; so that there go 24 bushels to make the septier, and 288 to make the muid. It is divided into 4 picotins, the picotin containing 2 quarts, or 4 litrons. The bushel for salt is divided into 2 half-bushels, 4 quarters, 8 half-quarters, and 16 litrons; 4 bushels make a minot, 16 a septier, and 192 a muid. The bushel for wood is divided into halves, quarters, and half-quarters. 8 bushels make the minot, 19 a mine; 20 mines, or 320 bushels, the muid. For plaster, 12 bushels make a sack, and 36 sacks a muid. For lime, 3 bushels make a minot, and 48 minots a muid. The minot is by ordonnance to be 11 inches 9 lines high, and 14 inches 8 lines in diameter. The minot is composed of 3 bushels, or 16 litrons; 4 minots make a septier, and 48 a muid. The French mine is no real vessel, but an estimation of several others. At Paris, the mine contains 6 bushels, and 24 make the muid; at Rouen, the mine is 4 bushels; and at Dieppe, 18 mines make a Paris muid. The septier differs in different places: at Paris, it contains 2 mines, or 8 bushels, and 12 septiers the muid; at Rouen the septier contains 2 mines or 12 bushels. Twelve septiers make a muid at Rouen as well as Paris; but 12 of the latter are equal to 14 of the former. At Toulon, the septier contains a mine and a half; three of which mines make the septier of Paris. The muid, or muy of Paris, consists of 12 septiers, and is divided into mines, minots, bushels, &c. That for oats is double that for other grain, *i. e.*, contains twice the number of bushels. At Orleans, the muid is divided into mines, but those mines only contain two Paris septiers and a half. In some places they use the tun instead of the muid, particularly at Nantes, where it contains 10 septiers of 16 bushels each, and weighs between 2,200 and 2,250 pounds. Three of these tuns make 28 Paris septiers. At Rochelle, &c., the tun contains 42 bushels, and weighs two per cent. less than that of Nantes. At Brest, it contains 20 bushels, is equal to 10 Paris septiers, and weighs about 2,240 pounds.

Dutch, Swedish, Polish, Prussian, and Muscovite. In these places, they estimate their dry things on the foot of the *last, lest, leth, lecht;* so called according to the various pronunciations of the people who use it. In Holland, the last is equal to 19 Paris septiers, or 38 Bordeaux bushels, and weighs about 4,560 pounds; the last they divide into 27 muids, and the muid into 4 scheples. In Poland, the last is 40 Bordeaux bushels, and weighs about 4,800 Paris pounds. In Prussia, the last is 133 Paris septiers. In Sweden and Muscovy, they measure by the great and little last, the first containing 12 barrels, and the second half as many. In Muscovy, they likewise use the chefford, which is different in various places; that of Archangel is equal to three Rouen bushels.

Italian. At Venice, Leghorn, and Lucca, they estimate their dry things on the foot of the staro or staio. The staro of Leghorn weighs 54 pounds; 112⅞ are equal to the Amsterdam last. At Lucca, 119 staros make the last of Amsterdam. The Venetian staro weighs 128 Paris pounds; the staro is divided into four quarters. Thirty-five staros and one fifth, or 140 quarters and four-fifths, make the last of Amsterdam. At Naples, and other parts, they use the tomolo, or tomalo, equal to one-third of the Paris septier. Thirty-six tomoli and a half make the carro, and a carro and a half, or 54 tomoli, make the last of Amsterdam. At Palermo, 16 tomoli make the salma, and 4 mondili the tomolo. Ten salmas and three-sevenths, or 171 tomoli and three-sevenths, make the last of Amsterdam.

Flemish. At Antwerp, &c., they measure by the viertel, 32½ whereof make 19 Paris septiers. At Hamburg, the schepel; 90 whereof make 19 Paris septiers.

Spanish and Portuguese. At Cadiz, Bilboa, and St Sebastian, they use the fanega; 23 whereof make the Nantes or Rochelle tun, or 9½ Paris septiers, though the Bilboa fanega is somewhat larger, insomuch that 21 fanegas make a Nantes tun. At Seville, &c., they use the anagoras, containing little more than the Paris mine; 36 anagoras make 19 Paris septiers. At Bayonne, &c., the concha; 30 whereof are equal to 9½ Paris septiers. At Lisbon, the alquiver, a very small measure; 240 whereof make 90 Paris septiers, 60 the Lisbon muids.

MEASURING, or MENSURATION, defined geometrically, is the assuming any certain quantity, and expressing the proportion of other similar quantities to the same.

MEASURING, defined popularly, is the using of a certain known measure, and determining thereby the precise extent, quantity, or capacity, of anything. In general, it constitutes the practical part of geometry. *See* MENSURATION.

MEASURING OF LINES, or quantities of one dimension, is called *longimetry;* and when those lines are not extended parallel to the horizon, *altimetry.* When the different altitudes of the two extremes of the lines are alone regarded, it is termed *levelling.*

MEASURING OF SUPERFICIES, or quantities of two dimensions, is variously denominated according to its subjects: when lands are the subject, it is called *geodesy*, or *surveying;* in other cases, simply *measuring.* The instruments used are the ten-foot rod, chain, compass, circumferentor, &c.

MEASURING OF SOLIDS, or quantities of three dimensions, is called *stereometry;* but where it relates to the capacities of vessels, or the liquors they contain particularly, *gauging.* The instruments for this art are the gauging-rod, sliding-rule, &c.

From the definition of measuring, where the measure is expressed to be similar or homogeneous to, *i. e.* of the same kind with, the thing measured, it is evident that, in the first case, or in quantities of one dimension, the measure must be a line; in the second, a superficies; and in the third, a solid. For example, a line cannot measure a surface; the art of measuring being no more than the application of a known quantity to the unknown, till the two become equal. Now, a surface has breadth, and a line has none; and if one line have no breadth, two or a hundred have none. A line, therefore, can never be applied so often to a surface as to be equal to it, *i. e.* to measure it. And from the like reasoning it is evident, a superficies, which has no depth, cannot become equal to, *i. e.* cannot measure, a solid which has.

While a line continues such, it may be measured by any part of itself; but when the line begins to flow, and to generate a new dimension, the measure must keep pace, and flow too; *i. e.* as the one commences superficies the other must do so too. Thus we come to have square measures, and cubic measures.

Hence we see why the measure of a circle is an arc or part of the circle, for a right line can only touch a circle in one point, but the periphery of a circle consists of infinite points. The right line, therefore, to measure the circle, must be applied infinite times, which is impossible. Again

the right line only touches the circle in a mathematical point, which has no parts nor dimensions, and has consequently no magnitude; but a thing that has neither magnitude nor dimensions bears no proportion to another that has, and cannot therefore measure it. Hence we see the reason of the division of circles into 360 parts or arcs, called *degrees*. *See* Arc, Circle, and Mensuration.

MECHANICS (from the Greek μηχανη, *art*) that branch of practical mathematics which treats of motion and moving powers, their nature, laws, effects, &c. This term, in a popular sense, is applied equally to the doctrine of the equilibrium of powers, more properly called *statics*, and to that science which treats of the generation and communication of motion, which constitutes *dynamics*, or mechanics strictly so called. *See* Force, Motion, Power, and Statics.

This science is divided by Newton into *practical* and *rational* mechanics, the former of which relates to the mechanical powers, viz., the lever, balance, wheel and axis, pulley, wedge, screw, and inclined plane; and the latter, or rational mechanics, to the theory of motion; showing, when the forces or powers are given, how to determine the motion that will result from them; and, conversely, when the circumstances of the motion are given, how to trace the forces or powers from which they arise.

Mechanics, according to the ancient sense of the word, considers only the energy of organs, or machines. The authors who have treated the subject of mechanics systematically have observed, that all machines derive their efficacy from a few simple forms and dispositions, which may be given to organs interposed between the agent and the resistance to be overcome; and to those simple forms they have given the name of *mechanical powers*, *simple powers*, *or simple machines*.

The practical uses of the several mechanical powers were undoubtedly known to the ancients, but they were almost wholly unacquainted with the theoretical principles of this science till a very late period; and it is therefore not a little surprising that the construction of machines, or the instruments of mechanics, should have been pursued with such industry, and carried by them to such perfection. Vitruvius, in his 10th book, enumerates several ingenious machines, which had then been in use from time immemorial. We find, that for raising or transporting heavy bodies, they employed most of the means which are at present commonly used for that purpose, such as the crane, the inclined plane, the pulley, &c.; but with the theory or true principles of equilibrium, they seem to have been unacquainted till the time of Archimedes. This celebrated mathematician, in his book of *Equiponderants*, considers a balance supported on a fulcrum, and having a weight in each scale; and taking as a fundamental principle, that when the two arms of the balance are equal, the two weights supposed to be in equilibrio are also of necessity equal, he shows, that if one of the arms be increased, the weight applied to it must be proportionally diminished. Hence he deduces the general conclusion, that two weights suspended to the arms of a balance of unequal length, and remaining in equilibrio, must be reciprocally proportional to the arms of the balance; and this is the first trace anywhere to be met with of any theoretical investigation of mechanical science. Archimedes also further observed, that the two weights exert the same pressure on the fulcrum of the balance, as if they were directly applied to it; and he afterwards extended the same idea to two other weights suspended from other points of the balance, then to two others, and so on; and hence, step by step, advanced towards the general idea of the centre of gravity, a point which he proved to belong to every assemblage of small bodies, and consequently to every large body, which might be considered as formed of such an assemblage. This theory he applied to particular cases, and determined the situation of the centre of gravity in the parallelogram, triangle, trapezium, parabola, parabolic trapezium, &c. &c. To him we are also indebted for the theory of the inclined plane, the pulley, and the screw, besides the invention of a multitude of compound machines; of these, however, he has left us no description, and therefore little more than their names remain.

We may judge of the very imperfect state in which the theory of mechanics was at that time, by the astonishment expressed by King Hiero, when Archimedes exclaimed, "Give me a place to stand on, and I will move the earth!" a proposition which could have excited no surprise in any person possessing a knowledge of the simple property of the lever. Of the theory of motion, however, it does not appear that even Archimedes possessed any adequate idea; the properties of uniform motion seem only to have engaged the attention of the ancients, and with those of accelerated and variable motion they were totally unacquainted: these were subjects to which their geometry could not be applied, the modern analysis being necessary to bring this branch of the science to perfection.

From the time of Archimedes till the commencement of the sixteenth century, the theory of mechanics appears to have remained in the same state in which it was left by this prince of Grecian science, little or no additions having been made to it during so many ages; but about this time, Stevinus, a Flemish mathematician, made known directly, without the introduction of the lever, the laws of equilibrium of a body placed on an inclined plane: he also investigated with the same success, many other questions on statics, and determined the conditions of equilibrium between several forces concurring in a common point, which comes, in fact, to the celebrated proposition relating to the parallelogram of forces; but it does not appear that he was at all aware of its consequences and application. In 1592, Galileo composed a treatise on statics, which he reduced to this single principle, viz:—It requires an equal power to raise two different bodies to heights having the inverse ratio of their weights: that is, whatever power will raise a body of two pounds to the height of one foot, will raise a body of one pound to the height of two feet. On this simple principle he investigated the theory of the inclined plane, the screw, and all the mechanical powers: and Descartes afterwards employed it in considering the statical equilibriums of machines in general, but without quoting Galileo, to whom he had been indebted or the first idea. After Stevinus and Galileo, Torricelli, Descartes, Huygens, Wallis, Wren, Newton, Liebnitz, Dechales, Oughtred, Keil, Delahire, Lagrange, Atwood, Prony, Emerson, Watt, Gregory, Young, &c., have in succession, since the period to which we have alluded, explained and applied the principles of this civilizing science in a wonderful manner.

MECHANICAL CARPENTRY, that part of the art of construction in timber which treats of the proper disposition of framing, so as to enable it to resist its own weight, or any additional load or pressure that may be casually laid upon it.

Mechanical Carpentry is so called from the principles of mechanics being employed in the construction of truss-framing, or other parts of the art; while Constructive Carpentry shows the rules for cutting and framing the timbers according to the proposed design. *See* that article.

The mechanical principles of a piece of carpentry are therefore first to be considered; because they must, in some measure, regulate the disposition and size of the timbers in

the design, after which they are to be prepared or formed according to the rules of constructive carpentry.

We shall here state a few of the elementary propositions, with the principles of trussing, and offer some observations on the best forms of bodies constructed of timber work, to be used under various circumstances. And as it is impossible, in complex parts, to give all the minutiæ with mathematical precision, this deficiency will, in a great measure, be compensated by general information.

The application of mechanical principles to carpentry was first introduced in this country by Professor Robinson, of Edinburgh, in the *Encyclopædia Britannica*, whose elaborate papers on this subject prepared the way for that investigation which has since been so ably followed out by others. In 1814, Mr. P. Nicholson drew up a complete article in every department of carpentry, for Rees's *Encyclopædia*, where this branch of the art, as depending upon the principles of mechanics, was particularly inculcated; and though several of the plates have been engraved and published some years ago, the manuscript relative to this particular branch has been retained for the article Roof, in this work, to which, indeed, it chiefly pertains.

In this application of mechanical science, Alex. Nimmo, Esq., F. R. S. E., the celebrated engineer, also published a very neat and well-connected theory of mechanical carpentry, under the article Carpentry, in the *Edinburgh Encyclopædia*; but perhaps the best work extant on this subject is Tredgold's Elementary Principles of carpentry, which contains a mass of the most valuable information, in the most convenient and available form.

Under the article Curb Roof, of the present Work, the reader will find an investigation of the best forms for a roof, restricted to certain data. The observations on the strength of timber are reserved for that article; but the practical rules derived therefrom will be here introduced preparatory to the general design of mechanical carpentry; and as these will be chiefly applicable to practice, we shall show the rules under their most simple form; discarding such as, though accurate, would be too complex for common use.

To find the comparative strength of timber.

Definition.—The depth of a piece of timber is its dimension in the direction of the pressure.

Proposition I.—*To find the comparative strength of different timbers.*

Rule.—Multiply the square of the depth of each piece into its thickness; and each product being divided by its respective lengths, will give the proportional strength of each.

Example.—Suppose three pieces of timber of the following dimensions:

The first 6 inches deep, 3 inches thick, and 12 feet long.

The second 5 inches deep, 4 inches thick, and 8 feet long.

The third 9 inches deep, 8 inches thick, and 15 feet long.

The comparative weight that will break each piece is required.

OPERATIONS.

First.	Second.	Third.
6 deep	5 deep	9 deep
6	5	9
—	—	—
36	25	81
3 thick	4 thick	8 thick
—	—	—
Length 12) 108	Length 8) 100	Length 15) 648 (43 and a fifth.
—	—	60
—	—	—
9	12½ and a half.	48
		45
		—
		3

Therefore, the weights that will break each are nearly in proportion to the numbers 9, 12, and 43, leaving out the fractions; in which it is to be observed, that the number 43 is almost five times the number 9; therefore the third piece of timber will bear almost five times as much weight as the first; and the second piece nearly once and a third the weight of the first piece; because the number 12 is one and a third greater than the number 9.

The timber is supposed to be everywhere of the same texture, otherwise these calculations cannot hold true.

Proposition II.—*Given the length, breadth, and depth of a piece of timber; to find the depth of another piece, whose length and breadth are given, so that it shall bear the same weight as the first piece, or any number of times more.*

Rule.—Multiply the square of the depth of the first piece into its breadth, and divide that product by its length: multiply the quotient by the number of times you would have the other piece to carry more weight than the first: and multiply the product by the length of the last piece, and divide the product by its width; out of this last quotient extract the square root, which is the depth required.

Example 1.—Suppose a piece of timber 12 feet long, 6 inches deep, 4 inches thick; another piece 20 feet long, 5 inches thick; required its depth, so that it shall bear twice the weight of the first piece.

	Proof.
6 deep	9.7
6	9.7
—	—
36	67.9
4	873
—	—
12) 144	94.09
—	1.91 remainder added
12	—
2 times	96.00
—	5
24	—
20 length	20) 480
—	—
5) 480	24
—	
96 (9.7, or 9.8 nearly, for the depth.	
81	
—	
187) 1500	
1309	
—	
191	

Example 2.—Suppose a piece of timber 14 feet long, 8 inches deep, 3 inches thick; required the depth of another

piece 18 feet long, 4 inches thick, so that the last piece shall bear five times as much weight as the first.

8
8
—
64
3
—
Half 7)192
—
27.4, &c.
5 times
—
137
9 half the length
—
4)1233
—
308.25 (17.5 the depth nearly.
1
—
27)208(
189
—
345)1925, &c.

As the lengths of both pieces of timber are divisible by the number 2, therefore half the length of each is used instead of the whole; the answer will be the same.

PROPOSITION III.—*Given the length, breadth, and depth of a piece of timber; to find the breadth of another piece whose length and depth are given, so that the last piece shall bear the same weight as the first piece, or any number of times more.*

RULE.—Multiply the square of the depth of the first piece into its thickness; the product divide by its length; multiply the quotient by the number of times it is required to have the last piece support more than the first; that product multiplied by the length of the last piece, and divided by the square of its depth, gives the breadth required.

Example 1.—Given a piece of timber 12 feet long, 6 inches deep, 4 inches thick; and another piece 16 feet long, 8 inches deep; required the thickness, so that it shall bear twice as much weight as the first.

6
6
—
36
4
—
3)144 Length
—
48
2
—
96
4
—
8)384
—
8) 48
—
6 thickness.

Or thus, at full length.

6 depth of the first piece.
6
—
36
4 thickness of the first piece
—
12)144
—
12
2 the number of times stronger
—
24
16 length of the last piece
—
144
24
—
8)384
—
8)48
—
6 thickness.

Example 2.—Given a piece of timber 12 feet long, 5 inches deep, 3 inches thick; and another piece 14 feet long, 6 inches deep; required the thickness, so that the last piece may bear four times as much weight as the first piece.

5
5
—
25
3
—
12)75
—
6.25
4
—
25.00
14
—
100
25
—
6)350
—
6)58.333
9.722

PROPOSITION IV.—*If a piece of timber sustain a force placed unequally between the extremes on which it is supported, the strength in the middle will be to the strength in that part of the timber so divided, as one divided by the square of half the length is to one divided by the rectangle of the two unequal segments; that is, in the reciprocal ratio of their products.*

Example 1.—Suppose a piece of timber 20 feet long, the depth and width immaterial; suppose the stress or weight to lie five feet distant from one of its ends, consequently from the other end 15 feet, then the above proportion will be

$\frac{1}{10 \times 10} = \frac{1}{100} : \frac{1}{5 \times 15} = \frac{1}{75}$ as the strength at five feet from the end is to the strength at the middle, or 10 feet, or as $5 \times 15 : 10 \times 10 : \frac{100}{75} = 1\frac{1}{3}$.

Hence it appears, that a piece of timber 20 feet long is one-third stronger at 5 feet distance from the bearing than it is in the middle, which is 10 feet, when cut in the above proportion.

Example 2.—Suppose a piece of timber 30 feet long; let the weight be applied 4 feet distant from one end, or more properly from the place where it takes its bearing, then from the other end it will be 26 feet, and the middle is 15 feet;

then $\frac{1}{15 \times 15} = \frac{1}{225} : \frac{1}{4 \times 26} = \frac{1}{104}$;

or as $4 \times 26 : 15 \times 15 = 2\frac{17}{104}$, or nearly $2\frac{1}{6}$.

Hence it appears, that a piece of timber 30 feet long will bear double the weight, and one-sixth more, at 4 feet distance from one end, than it will do in the middle, which is 15 feet distant.

Example 3.—Allowing that 266 pounds will break a beam 26 inches long, required the weight that will break the same beam when it lies at 5 inches from either end; then the distance to the other end is 21 inches; $21 \times 5 = 105$, the half of 26 inches is 13; therefore $13 \times 13 = 169$; consequently the strength at the middle of the piece is to the strength at 5 inches from the end, as $\frac{169}{169} :: \frac{169}{105}$; or as $1 : \frac{169}{105}$

The proportion is stated thus:

lb.
169
1 : —— : : 266 to the weight required.
105 169

2394
1596
266

105) 44954 (428
420

295
210

854
840

14

From this calculation, it appears that rather more than 428 pounds will break the beam at 5 inches' distance from one of its ends, if 266 pounds will break the same beam in the middle.

By similar propositions, the scantlings of any timber may be computed, so that they shall sustain any given weight; for if the weight that one piece will sustain be known, with its dimensions, the weight that another piece will sustain, of any given dimensions, may also be computed. The reader must observe, that although the foregoing rules are mathematically true, yet it is impossible to account for knots, cross-grained wood, &c., such pieces being not so strong as those which have straight fibres; and if care be not taken in choosing the timber for a building, so that the fibres be disposed in parallel straight lines, all rules which can be laid down will be useless. It will be impossible, however, to estimate the strength of timber fit for any building, or to have any true knowledge of its proportions, without some rule; as otherwise everything must be done by mere conjecture.

Timber is much weakened by its own weight, except it stand perpendicular to the horizon.

The bending of timber will be nearly in proportion to the weight laid on it. No beam ought to be trusted for any long time with above one-third or one-fourth part of the weight it will absolutely carry; for experiment proves, that a far less weight will break a piece of timber when hung to it for any considerable time, than what is sufficient to break it when first applied.

PROBLEM I.—*Having the length and weight of a beam that can just support a given weight in the middle, to find the length of another beam of the same scantling, that shall just break with its own weight.*

Let l = the length of the first beam;
L = the length of the second;
a = the weight of the first beam;
w = the additional weight that will break it.

Then $w + \frac{a}{2} = \frac{2w + a}{2}$ is the weight that will break the lesser beam.

Again, let w be the weight of the beam that breaks with its own weight; and because the weights that will break beams of the same scantling are reciprocally as their lengths:

$$\text{L} : l :: \frac{2w + a}{2} : l\,\frac{2w + a}{2\,\text{L}} = \text{W}.$$

But the weights of beams of the same scantlings are to each other as their lengths;

$$l : \text{L} :: \frac{a}{2} : \frac{a\,\text{L}}{2\,l} = \frac{\text{W}}{2}$$ half the weight of the greater beam.

Now, a beam supported at both ends cannot break with its own weight, unless half the weight of the beam be equal to the weight that will break it;

$$\text{therefore};\ \frac{a\,\text{L}}{2\,l} = l\,\frac{2w + a}{2\,\text{L}};$$

$$\text{consequently},\ a\,\text{L}^2 = l^2\,(2w + a)$$

$$\text{and},\ \text{L} = l\left(\frac{2w + a}{a}\right).$$

PROBLEM II.—*Having the weight of a beam that can just support a given weight in the middle; to find the depth of another beam similar to the former, so that it shall just support its own weight.*

Let d = the depth of the first beam;
x = the depth of the second beam;
a = the weight of the first beam;
w = the additional weight that will break the first beam.

Then will $w + \frac{a}{2}$, or $\frac{2w + a}{2}$ = the whole weight that will break the lesser beam.

And because the weights that will break similar beams are as the squares of their lengths,

$$d^2 : x^2 :: \frac{2w + a}{2} : \frac{2x^2 w + x^2 a}{2d^2} = \text{W}.$$

Then because the weights of similar beams are as the cubes of their corresponding sides:

$$d^3 : x^3 :: \frac{a}{2} : \frac{a\,x^3}{2\,d^3} = \text{W};$$

$$\text{therefore}\ \frac{a\,x^3}{2\,d^3} = \frac{2x^2 w + a\,x^2}{2\,d^2};$$

$$a\,x^3 = (2w + a) \times d;$$

consequently $a : a + 2w :: d : x^3 =$ the depth required.

As the weight of the lesser beam is to that of the greater beam, together with the additional weight; so is the depth of the lesser beam to the cube of the depth of the greater.

Note.—Any other corresponding sides will answer the same purpose, being all proportional to each other.

Example.—Suppose a beam, whose weight is one pound, and its length 10 feet, to carry a weight of 399.5 pounds; required the length of a beam similar to the former, of the same matter, so that it shall break with its own weight:

$$\text{then}\ a = 1$$
$$w = 39.5$$
$$\text{and}\ a + 2w = 800 = 1 + 2 \times 399.5$$
$$d = 10$$

Then, by the last problem, it will be

1 : 800 : : 10
10

8000 = x, for the length of a beam that will break by its own weight.

PROBLEM III.—*The weight and length of a piece of timber being given, and the additional weight that will break it; to find the length of a piece of timber similar to the former, so that this last piece of timber shall be the strongest possible.*

Put l = the length of the piece given;
w = half its weight;
w = the weight that will break it;
x = the length required.

Then, because the weights that will break similar pieces of timber are in proportion to the squares of their lengths,

$$l^2 : x^2 : : \mathrm{w} + w : \frac{\mathrm{w}\,x^2 + w\,x^2}{l^2} = \text{the whole weight that}$$

will break the beam.

And because the weights of similar beams are as the cubes of their lengths, or any other corresponding sides,

$$l^3 : x^3 : : w : \frac{w\,x^3}{l^3} \text{ the weight of the beam;}$$

consequently, $\frac{\mathrm{w}\,x^2 + w\,x^2}{l^2} - \frac{w\,x^3}{l^3}$ is the weight that breaks the beam = a maximum; therefore its fluxion is nothing: that is,

$$2\,\mathrm{w}\,x\,\dot{x} + 2\,w\,x\,\dot{x} - \frac{3\,w\,x^2\,x}{l} = 0.$$

$$2\,\mathrm{w} + 2\,w = \frac{3\,w\,x}{l};$$

$$\text{hence, } x = l \times \frac{2\,\mathrm{w} + 2\,w}{3\,w}.$$

Hence it appears from the foregoing problems, that large timber is weakened in a much greater proportion than small timber, even in similar pieces, therefore a proper allowance must be made for the weight of the pieces, as in the following example.

Suppose a beam, 12 *feet long, and a foot square, whose weight is three hundred-weight, to be capable of supporting* 20 *hundred-weight; what weight will a beam* 20 *feet long,* 15 *inches deep, and* 12 *thick, be able to support?*

12 inches square	15
12	15
144	75
12	15
12) 1728	225
144	12
	2,0) 270,0
	135

	Inches.
Now the solid contents of the first beam is . . .	20736
and that of the second	43200

But the weights of beams are as their solid contents; therefore,

20736 : 43200 : : 3
3

cwt. lb.
20736) 129600 (6 28 = the weight of the second beam.
124416

5184
112

10368
5184
5184

20736) 580608 (28
41472

165888
165888

144 : 135 : : 21.5 by Proposition I.
215

675
135
270

12) 2902.5

12) 241.875

20.15625
112

31250
15625
15625

17.50000
16

30
5

8.0

21 cwt. 56 lb. is the weight that will break the first beam, and 20 cwt. 17 lb. 8 oz. the weight that will break the second beam. Deduct out of these half their own weight:

cwt.	lb.	oz.	
20	17	8	
3	14	0	half
17	3	8	

Now 20 cwt. is the additional weight that will break the first beam; and 17 cwt. 3 lb. 8 oz. the weight that will break the second; in which the reader will observe, that 17 cwt. 3 lb. 8 oz. bears a much less proportion to 20 cwt. than 20 cwt. 17 lb. 8 oz. bears to 21 cwt. 56 lb. From these examples, it is evident that a proper allowance ought to be made for all horizontal beams: that is, half the weights of beams ought to be deducted out of the whole weight they will carry, and the remainder is the weight which each piece will bear.

If several pieces of timber of the same scantling and length be applied one above another, and supported by props at each end, they will be no stronger than if they were laid side by side; or, which is the same thing, the pieces that are applied one above another are no stronger than one single piece whose width is the width of the several pieces collected into one, and its depth that of one of the pieces; it is therefore useless to cut a piece of timber lengthwise, and apply the pieces so cut one above each other, for these pieces are not so strong as before, even though assisted by bolting.

Example.—Suppose a girder 16 inches deep, 12 inches thick, the length immaterial, and let the depth be cut lengthwise into two equal pieces; then will each piece be 8 inches deep, and 12 inches thick. Now, according to the rule of proportioning timber, the square of 16 inches, that is the depth before it was cut, is 256, and the square of 8 inches is 64; but twice 64 is only 128, therefore it appears that the two pieces applied one above another, is but half the strength of the solid piece, because 256 is double 128.

If a girder be cut lengthwise in a perpendicular direction, the ends turned contrary, and then bolted together, it will be but very little stronger than before it was cut; for although the ends, being turned, give to the girder an equal strength throughout, yet wherever a bolt is, there the girder will be weaker; and it is doubtful whether it will be any stronger for this process of sawing and bolting.

Figure 1.—If there be two pieces of timber of an equal scantling, the one lying horizontally and the other inclined, the horizontal piece being supported at the points *e* and *f*, and the inclined piece at *c* and *d*, perpendicularly over *e* and *f*; according to the principles of mechanics, these pieces will be equally strong. But to reason a little on this matter, let it be considered, that though the inclined piece, D, is longer, yet the weight has less effect upon it when placed in the middle, than the weight at *h* has upon the horizontal piece, C, the weights being the same; it is therefore reasonable to conclude, that in these positions the one will bear equal to the other.

From different experiments, it has been found that the law of resistance in a piece of timber does not exactly obey the foregoing rules. The labour and expense attending such experiments, on a scale likely to be at all useful, far exceed the abilities of individuals, who might otherwise be disposed to investigate this useful branch of mechanical knowledge. This grand objection, no doubt, has been the cause why so little has been done to determine the law of resistance by experiments; yet, as we are not absolutely without some lights, we shall proceed to lay them before our readers, in as concise a manner as the nature of the subject will admit.

The first authority to our purpose is what Belidor has given on the subject, in his *Science des Ingenieurs.*

Belidor's Experiments.

In the subjoined table, the column B contains the breadth of the pieces, in inches; D contains their depths; the column L contains their lengths; P the weight (in pounds) which broke them, when hung on their middles.

In order to obtain the best idea of the strengths of pieces of different dimensions with more certainty, three pieces of each dimension were tried; a medium among them being more accurate than a single experiment.

The column M contains those mediums.

The experiments were made on oak, of equal quality, and tolerably well seasoned.

	B	D	L	P	M
Experiment 1, ends loose.....	1	1	18	400 415 405	406
Experiment 2, ends firmly fixed	1	1	18	600 600 624	608
Experiment 3, ends loose.....	2	1	18	810 795 812	805
Experiment 4, ends loose.....	1	2	18	1570 1580 1590	1580
Experiment 5, ends loose.....	1	1	36	185 195 180	187
Experiment 6, ends fixed.....	1	1	36	285 280 285	283
Experiment 7, ends loose.....	2	2	36	1550 1620 1585	1585
Experiment 8, ends loose.....	$1\frac{1}{3}$	$2\frac{1}{3}$	33	1665 1675 1640	1660

By comparing the 1st experiment with the 3d, the strength appears proportional to the breadth; the length and depth of each piece being the same.

By comparing the 1st and 4th experiments, the strength appears as the square of the depth, nearly; the breadth and length being always the same.

By comparing the 1st and 5th experiments, the strength is seen to be nearly as the lengths, inversely; the breadth and depth of each piece being the same.

By comparing experiments 5 and 7, the strengths will appear to be nearly in proportion to the breadth, multiplied by the square of the depth; the length being the same in both.

The 1st and 7th experiments show the strengths to be as the square of the depth, multiplied by the breadth, and divided by the length.

Experiments 1 and 2, and 5 and 6, show the increase of the strength by fastening the ends, to be in the proportion of 2 to 3.

From the foregoing experiments, it appears that the rule founded upon the Galilean hypothesis, for finding the comparative strength of timber, is nearly true. But as it would be wrong to draw conclusions from timbers of so small scantlings as in the above experiments, we shall, after making the following observation, give an abstract of the experiments of M. de Buffon, as well as of those of M. du Hamel, men of acknowledged abilities, who were directed by the French government to make experiments on this subject; and who were supplied with ample funds and apparatus for the purpose, and had the choice of the best subjects in all the forests of France. The reports of M. de Buffon may be found in the *Memoirs of the French Academy*, for the years 1740, 1741, 1742, 1768; and those of M. du Hamel, in his work, *Sur l'Exploitation des Arbres, et sur la Conservation et le Transportation de Bois.* But we observe, the chief cause of the irregularity in such experiments, is the fibrous, or rather plated texture of timber, which consists of annual additions, whose cohesion with each other is vastly weaker than that of their own fibres. Let *Figure* 2, represent the section of a tree, and A B C D, and *a b c d*, the sections of two quarterings, to be cut out of it, for experiment; let A D and *a d*, be the depths; and D C, *d c*, the breadths; the quartering A B C D

will be the strongest for the same reason that an assemblage of planks set edgewise, will be stronger than the same number of planks laid above each other.

M. de Buffon found that the strength of A B C D, was to that of *a b c d*, in oak, nearly as 8 to 7.

The authors of the different experiments, we have reason to fear, were not very careful that their bars had their plates all disposed the same way.

As great beams occupy much, if not the whole section of the tree, it has happened that their strength is less than in proportion to that of a small lath quartering or scantling; for which reason a set of experiments ought to be carefully made on each, as all large buildings require a great number of both kinds: as girders and other beams for supporting large weights, so small bars are employed in making joists, rafters, purlins, &c., all of which are for the purpose of carrying or discharging weights.

M. de Buffon's Experiments.

The following table exhibits a number of experiments on bars of sound oak, clear of knots, each bar being four inches square.

The column No. 1, contains the length of the bar in feet, between the two props.

The column No. 2, contains the weight of the bar, the second day after it was felled, in pounds.

The column No. 3, contains the number of pounds necessary for breaking the bar in a few minutes.

The column No. 4, contains the number of inches it bent down before breaking.

The column No. 5, contains the number of minutes that each respective piece was in breaking.

In this table two bars were tried of each length: each of the first three pairs consisted of two cuts of the same tree; the one next to the root was always found to be the heaviest, stiffest, and strongest; from which M. de Buffon recommends a certain and sure rule for estimating the goodness of timber by its weight: he finds that this is always the case when the timber has grown vigorously, forming thick annual layers. But he also observes, that this is only during the advances of the tree to maturity, for the strength of the different circles approaches gradually to an equality during a healthy growth.

1	2	3	4	5
7	60	5350	3.5	29
	56	5275	4.5	22
8	68	4600	3.75	15
	63	4500	4.7	13
9	77	4100	4.85	14
	71	3950	5.5	12
10	84	3625	5.83	15
	82	3600	6.5	15
12	100	3050	7.	
	98	2925	8.	

Experiments on other sizes were made in the same manner: a pair, at least, of each length and scantling was taken; the mean result is contained in the following table. The beams were all square, and their sizes, in inches, are placed at the head of the columns; and their length, in feet, in the first column. The column A exhibits the strength which each of the five-inch bars ought to have, by the theory.

M. de Buffon found, by numerous experiments, that oak timber lost much of its strength by drying or seasoning; and therefore, in order to secure uniformity, his trees were all felled in the same season of the year, were squared the day after, and tried on the third day. Trying them in this green state, gave him an opportunity of observing a very curious phenomenon.

When the weights were laid briskly on, nearly sufficient to break the log, a smoke was observed to issue from each end, accompanied with a hissing noise, which continued while the tree was bending and cracking; owing to the strain excited by bending: in which state it must be both compressed and extended.

	4	5	6	7	8	A
7	5312	11525	18950	32200	47649	11525
8	4550	9787	15525	26050	39750	10085
9	4025	8308	13150	22350	32800	8964
10	3612	7125	11250	19475	27750	8068
12	2987	6075	9100	16175	23450	6723
14		5300	7475	13225	19775	5763
16		4350	6362	11000	16375	5042
18		3700	5562	9245	13200	4482
20		3225	4950	8375	11487	4034
22		2975				3667
24		2162				3362
28		1775				2881

From the above experiments, some conclusions respecting the law of the strength of oak timber may be deduced, from which it will be seen whether the theory already established be sufficiently accurate; or, if not, they will show in what manner it ought to be corrected.

M. de Buffon considers the experiments upon the five-inch bars as the standard of comparison, having both extended these to a greater length, and having tried more pieces of each length.

The theory determines the relative strengths of bars of the same section, to be inversely as their lengths; but, if the five experiments in the first column be excepted, there will be found a very great deviation from this rule: thus the five-inch bar of 28 feet long should have half the strength of that of 14 feet, or 2650, whereas it is but 1775; the bar of 14 feet should have half the strength of the 7 feet, or 5762; whereas it is but 5300; and in like manner the fourth of 11,525 is 2881; but the real strength of the 28-inch bar is but 1775. The column A exhibits the strength that each of the five-inch bars ought to have by the theory, which decreases much slower than those shown by the experiment; and therefore it appears, that the strength of different pieces of timber decreases much quicker than that of the inverse ratio of their lengths; but in what ratio precisely the strength decreases, it would be almost impossible to know, as there is not a sufficient number of experiments for the purpose; the few that have been tried are so very anomalous, as will appear by taking the differences between those in the third column, found by the experiments, from their respective numbers under A in the seventh column, as found by the rule, which are respectively 298, 656, 943, 648, 463, 692, 782, 809, 692, 1200, 1106: by comparing these numbers together, it is easy to see the impossibility of discovering any progression, or regular increase; for example, the third difference is greater than any of the preceding, and less than any of the succeeding, except the two last; and therefore it appears, that no rule can be founded on these experiments for finding the relative strength of timber, but what will in many cases differ

very considerably from that which ought to correspond to it; in the table, however, the rule given in our former calculations may, if somewhat corrected, correspond nearly with the five-inch bars, as follows:—from the length of the required piece, take the 7 feet length, and multiply the difference by the number 1474, divide that product by the length, subtract the quotient from the number of pounds found by the former rule, and the remainder will be the answer.

M. de Buffon uniformly found that two-thirds of the weight which was sufficient to break a beam at first, sensibly impaired its strength, and frequently broke it, at the end of two or three months; and one-half of this weight brought it to a certain curvature, which did not increase after the first minute or two, and may be borne by the beam for any length of time.

One-third seemed to have no permanent effect on the beam; but it recovered its rectilinear shape completely, even after it had been loaded several months, provided the timber was seasoned when first loaded: that is to say, one-third of the weight which would quickly break a seasoned beam, or one-fourth of what would break one just felled, may lie on it for ever, without giving the beam a set.

The agreement of the numbers, found by the rule of the breadth being multiplied by the square of the depth, appears to deviate less from the experiments of Buffon, than that of the inverse ratio of the length; but even this rule, applied to softer woods, will differ greatly from the truth, which must be evident when we consider a beam just breaking, that it will be strongly compressed on the side nearest to the axis of fracture, and the opposite side will be greatly extended; consequently, there must be some point between the fulcrum and the opposite side, which will neither be extended nor compressed; and all the fibres lying between this point and the fulcrum, being in a state of compression, can offer little resistance against the fracture; the fibres on the other side only being exerted.

This is fully verified by some curious

Experiments by M. du Hamel.

He took 16 bars of willow, two feet long and half an inch square, and supported them by props under the ends: he broke them with weights hung on their middle. He broke four of them by weights of 40, 41, 47, and 52 pounds; the mean is 45.

He then cut four of them one-third through, on the upper side, and filled up the cut with a thin piece of harder wood, stuck in very tight: these were broken by 48, 54, 50, and 52, the mean of which is 51.

He cut other four half through; they were broken by 47, 49, 50, and 45, the mean of which is 48.

The remaining four were cut two-thirds, and their mean strength was 42.

Another set of Experiments, still more remarkable.

Six battens of willow, 36 inches long, and 1½ square, were broken by 525 pounds, at a medium.

Six bars were cut one-third through, and the cut filled with a wedge of hard wood, struck in with little force; these broke with 551 pounds.

Six bars were cut half through, and the cut was filled up in the same manner: they broke with 542 pounds.

Six bars were cut three-fourths through, and after being loaded till nearly broken, were unloaded, the wedge was taken out of the cut, and a thicker wedge was put in tight, so as to make the batten straight again, by filling up the space left by the compression of the wood: and it then broke with 577 pounds.

Of the Absolute Strength of Timber.

The strain occasioned by pulling timber in the direction of its length is called *tension;* it frequently occurs in roofs, and is therefore worthy of consideration.

The absolute strength of a fibre, or small thread of timber, is the force by which every part of it is held together, which is equal to the force that would be required to pull it asunder; and the force which would be required to tear any number of threads asunder is proportional to that of their sum; but the areas of the sections of two pieces of timber composed of fibres of the same kinds are as the number of fibres in each; and therefore the strength of the timber is as the area of the sections.

Hence all prismatic bodies are equally strong; that is, they will not break in one part rather than in another.

Bodies which have unequal sections will break at their smallest part; and therefore, if the absolute strength which would be required to tear a square inch of each kind of timber be known, we shall be able to determine the strength of any other quantity whatever.

The following table is taken from Muschenbroëk's experiments; he has described his method of trial minutely; the woods were all formed into slips fit for his apparatus, and part of the slip was cut away to a parallelopiped one-fifth of an inch square, and therefore the twenty-fifth part of a square inch in section; the absolute strengths of a square inch were as follow:—

	lb		lb
Locust tree	20,100	Pomegranate	9,750
Jujeb	18,500	Lemon	2,950
Beech oak	17,300	Tamarind	8,750
Orange	15,500	Fir	8,330
Alder	13,900	Walnut	8,130
Elm	13,200	Pitch pine	7,650
Mulberry	12,500	Quince	6,750
Willow	12,500	Cypress	6,000
Ash	12,000	Poplar	5,500
Plum	11,800	Cedar	4,880
Elder	10,000		

M. Muschenbroëk has given a very minute detail of the experiments on the ash and walnut, stating the weight requisite to tear asunder slips taken from the four sides of the tree, and on each side in a regular progression, from the centre to the circumference. The numbers of this table corresponding to the two timbers, may therefore be considered as the average of more than fifty trials made on each; and he says that all the others were made with the same care, and therefore there is no reason for not confiding in the results.

Practical Observations.

The following observations on wood will be of great use to the practical carpenter, in making a proper choice of timber, according to the purposes for which he may want to employ it.

1. The wood immediately surrounding the pith, or heart, is the weakest; and its inferiority is so much the more remarkable as the tree is older. Muschenbroëk's detail of experiments is decidedly in the affirmative. M. de Buffon, on the other hand, says that his experience has taught him that the heart of a sound tree is the strongest, but he gives no instances. It is certain, from other experiments, on large oaks and firs, that the heart is much weaker than the exterior parts.

2. The wood next to the bark commonly called *white*, or *blea*, is also weaker than the rest; and the wood gradually increases in strength as we recede from the centre to the blea.

3. The wood is stronger in the middle of the trunk than at the springing of the branches, or at the root; and the wood of the branches is weaker than that of the trunk.

4. The wood on the north side of all trees, which grow in the European climates, is the weakest, and that of the south side the strongest; and the difference is most remarkable in hedge-row trees, and such as grow singly.

The heart of a tree is never in its centre, but always nearer to the north side, and the annual coats of wood are thinner on that side. In conformity to this, it is a general opinion of carpenters, that the timber is stronger whose annual plates are thicker. The tracheæ, or air-vessels, are weaker than the simple ligneous fibres. These air-vessels are the same in diameter and number of rows in all trees of the same species, and they make the visible separation between the annual plates. Therefore, when these are thicker, they contain a greater proportion of the simple ligneous fibres.

5. All woods are more tenacious while green, and lose very considerably by drying after the tree is felled.

We shall conclude these observations with the following useful problem.

To cut the strongest beam possible out of a round tree, whose section is a given circle.

Figure 3.—Let A E B F be the section; draw the diameter A B, and divide it into three equal parts at C and *e*: from either of these points, as *e*, draw *e* E perpendicular to A B, cutting the circumference at E; draw A E and E B; through the points A and B draw A F and B F respectively parallel to E B and E A, cutting each other at F; and A E B F will be a section of the strongest beam that can possibly be cut out of the tree, A E B F; for the square of the depth, A E, or F B, multiplied into the breadth, E B, or F A, is then the greatest that can be produced.

From this it is plain, that the strongest beam which can be cut out of a round tree does not contain the most timber; for the greatest rectangle that can be inscribed in a circle is a square, and therefore the square F G H I is greater than the rectangle A F B E, and yet is not the strongest.

To support a piece of timber by means of two props resting on the ground, so that it shall have no tendency to go to either side.

Figure 4.—Let E I be a piece of timber, and G its centre of gravity; then the position, E I, of the timber being given, with the direction of one of the props, H I, and the point, E, where the other is to be placed; to find its length and position, draw G K perpendicular to the horizon; produce H I to K, and draw K E to meet the ground in F, then E F is the length and direction of the post.

To ascertain the proportions between the weight of the piece of timber and the compression of the props.

On the plumb-line G K, take any distance, K M; draw M N parallel to E K, cutting I K in N; and draw M L parallel to I K, cutting E K in L; then, if K M represent the weight of the piece of timber, K N will represent its pressure on the prop I H, and K L its pressure on the prop E F.

The *compression of timber* is another consideration worthy of attention.

In considering strains of this kind, it is absolutely impossible to conceive how a piece of timber that is perfectly straight can be bent, crippled, or broken, by any force whatever acting at the extremes. But suppose the smallest force whatever, acting in the middle, on a direction perpendicular to the length, this force will be sufficient to give it a small degree of curvature; and if a strong force be supposed to act at the ends at the same time, each pressing the timber in the direction of its length, these forces may instantly contribute towards breaking it.

It is easy, therefore, to conceive, that if a piece of timber be the least bent whatever, or if the fibres of that timber be not quite straight, there is a certain force which, if acting at the ends, will break it. Thus, suppose the column, A C B, *Figure* 5, resting on the ground at B, and loaded at the top with a weight, A, acting in a vertical direction A B; and if the fibres, or the piece A C B, is in the smallest degree crooked, the degree of curvature, by the pressure of the two ends, will be increased, until the fibres are bent to their utmost extent, and the smallest addition at the ends will break it.

The first writer who considered the compression of columns with attention, was the celebrated Euler, who published, in the *Berlin Memoirs* for 1757, his Theory on the Strength of Columns. The general proposition established by this theory is, that the strength of prismatic columns is in the direct quadruplicate ratio of their diameters, and the inverse ratio of their lengths; he prosecuted this subject in the *Petersburg Commentaries* for 1778, confirming his former theory. Muschenbroëk has compared the theory with experiment, but the comparison has been very unsatisfactory; the difference from the theory being so enormous as to afford no argument for its justness; neither do they contradict it, for they are so very anomalous as to afford no conclusion or general rule whatever.

Proposition V. *Figure* 6.—*If a heavy body*, A B C D, *be supported by two oblique strings*, D E *and* C F, *in a vertical plane, a straight line drawn through the intersection will pass through the centre of gravity of the body.*

It is shown under the article Lever, that if any three forces act upon a point, or body, their directions will tend to the same point, or be parallel to each other: now every body acts with its full force in one point only, viz., in the centre of gravity of that body, and in a direction perpendicular to the horizon: that is to say, if the weight of the body be supposed to be collected into the centre of gravity, the effect would be the same, provided the directions of the other two sustaining forces remained the same: therefore, if a body be sustained at E and F, it will revolve round these points till the line, G H, passing through the intersection, H, of the two strings, D E and C E, and the centre of gravity, G, become perpendicular to the horizon.

Corollary 1.—Hence, if any body be supported by two strings, it may also be supported by two planes perpendicular to these strings; provided the two points of the body supported be in the direction of the strings; for every body acting upon a plane, acts in a line perpendicular to that plane.

Corollary 2.—Hence also a body may be supported by two props in any two directions in which it may be supported by strings; provided the surface of the body at the points of contact, at the ends of the props, be planes at right angles to the strings.

Corollary 3.—Hence all the properties that have been demonstrated of three forces acting upon a body supposed void of weight, will equally flow from a heavy body supported by two strings, by substituting the weight of the body for the middle force; and hence, if the direction of any force supporting a heavy body be given, the other may easily be found.

Proposition VI.—*Given the position in which a body should be placed, and the position of a plane supporting the body at one end; to find the position of another plane, to support it at another given point; and to find the pressure on the planes, the weight of the body being given.*

Through the centre of gravity of the body draw a vertical line, and through the point on which the body rests on the given plane draw a line perpendicular to that plane, meeting the vertical line; from their intersection draw a line to the other point to be supported; from that point draw a plane at right angles to this line, which will be the direction of the plane required.

To find the intensity of the forces, take any distance on the vertical line to represent the weight of the beam from the intersection; on that line, as a diagonal, complete a parallelogram, whose sides are in the directions of the lines perpendicular to the supporting planes; and the side of the parallelogram perpendicular to either plane will represent the force on that plane.

Example 1. *Figure* 7.—Let the body A B C D lie upon the top of the wall, K C, at C, so as to touch the lower edge, B C, of the body at that point, B; it is required to find the direction of a plane that will support the lower end at B; and to find the pressure of the body on the wall and on the plane.

Through the centre of gravity, G, of the body, draw the vertical line G F; draw C F perpendicular to C B; join F B; and draw B I perpendicular to F B; and B I is the direction of the plane required. On the vertical line, F, make F M to represent the weight of the body, and complete the parallelogram L M N F; then F N represents the force on the wall-head in the direction C F, and F L the force acting perpendicular to the plane in the direction B F. But if the vertical and horizontal thrusts on the wall at C be required, draw N P perpendicular to F G, meeting it in P; then the force F N is resolved into two forces, F P and P N; P N representing the horizontal part of the force, viz., that which pushes the wall in a direction parallel to the horizon, and F P the other part which tends to press it downwards in a direction perpendicular to the horizon.

Example 2.—*Figure* 8.—Let the sloping body, A B C D, be supported by a wall at its lower end, D, which coincides with the surface of the body; and let G be the centre of gravity; it is required to cut a notch out of the body at the upper end, C, so that it may rest upon the top of a wall which is made to fit the notch, and to find the pressure on the walls. Draw the vertical line G E; from D draw D E perpendicular to D C; join E C, and draw C F at right angles to it; then the notch, H C F, being cut, the body, A B C D, will be at rest.

To find the pressure on the walls, complete the parallelogram E I K L, having a given angle, D E C, and its diagonal on the given line E G: now if K E represent the weight of the body, I E will represent the pressure in the direction, D E, upon the wall at D, and L E the pressure in the direction C E.

The horizontal and perpendicular pressures upon each wall may be found, as in the first example, by resolving each of the forces, I E and L E, into two, one of which is perpendicular to the horizon, and the other parallel to it.

Scholium.—It must be observed in this example, that the notch cut out at C will remove the centre of gravity nearer the lower end, D, and consequently alter the slope, C F; but as this can only be in a small degree, the equilibrium will hardly be affected by it when the notch is minute.

Example 3. *Figure* 9.—Let one of the corners of a sloping body, A B C D, rest upon the level top of a wall at D; it is required to find the position of a notch cut out of the upper end, C, so that the body may rest upon a wall made to fit the notch.

Let the small part, F C H, be so cut that C H may be parallel to the horizon, then the body will be supported by the two walls, at C and D. For if D I, G K, and C L, be drawn perpendicular to the horizon, these lines, being produced, may be supposed to meet at an infinite distance.

To find the pressure on the walls, join L C, and produce the vertical line K G to meet it in L; then, if G be supposed to be the weight of the body, the pressure on D will be $\frac{E C \times G}{D C}$, and the pressure on C will be $\frac{D L \times G}{D C}$.

Example 4. *Figure* 10.—Let the body, A B C D, be with its upper end against the vertical face of a wall at C, it is required to find the position of a plane supporting the lower end, D, so that the body may be at rest. Draw the vertical line G E, and draw C E perpendicular to the face of the wall, C L; join E D, and draw D F perpendicular to E D; then D F is the position of the plane required. Complete the parallelogram E H I K: then the pressure on D and C, and the weight of the body, are to each other as E H, E K, E I.

The following, from Professor Robinson, will also be found interesting:

Figure 11.—If a body, or any part of a body, be at once pressed in the two directions A B, A C, and if the intensity or force of those pressures be in the proportion of these two lines, the body is affected in the same manner as if it were pressed by a single force acting in the direction A D, which is the diagonal of the parallelogram A B D C formed by the two lines, and whose intensity has the same proportion to the intensity of each of the other two that A D has to A B or A C.

This proposition has been already treated at some length under the article Lever. And D. Bernouilli has demonstrated it in the first volume of the *Comment. Petropol.* to which, as well as to D'Alembert's improvement, in his *Opuscles*, and in the *Comment. Taurinens.* the reader is referred for a very accurate view of the subject. But nothing can possibly conduce so fully to the practitioner's advantage as to verify the theoretical demonstrations by actual experiments.

Figure 12.—Let the threads A *d*, A F *b*, and A E *c*, have the weights *d*, *b*, and *c*, appended to them, and let two of the threads be laid over the pulleys F and E. By this apparatus, the knot A will be drawn in the directions A B, A C, and A K. If the sum of the weights *b* and *c* be greater than that of the single weight *d*, the assemblage will of itself settle in a certain determined form; if the knot A be pulled out of its place, it will always return to it again, and will rest in no other position. For example, if the three weights be equal, the threads will always make equal angles, of 120 degrees each, round the knot. If one of the weights be three pounds, another four, and the third five, the angle opposite to the thread stretched by five pounds will be always square, &c. When the knot A is thus in equilibrio, we must infer, that the action of the weight *d*, in the direction A *d*, is in direct opposition to the combined action of *b*, in the direction A B, and of *c*, in the direction A C. Therefore, if *d* A be produced to any point, D, and A D be taken to represent the magnitude of the force, or pressure exerted by the weight *d*, the pressures exerted on A, by the weights *b* and *c*, in the directions A B, A C, will in fact be equivalent to a pressure acting in the direction A D, whose intensity is represented by A D. If we now measure off by a scale on A F and A E the lines A B and A C, having the same proportions to A D that the weights *b* and *c* have to the weight *d*, and if we draw D B and D C, we shall find D C to be equal and parallel to A B, and D B equal and parallel to A C; so that A D is the diagonal of a parallelogram A B D C. This will always be the case, whatever weights be made use of; only care must be taken that the weight acting without the intervention of a pulley be less than the sum of the other two: for if any one of the weights exceed

the sum of the other two, it will prevail, and drag them along with it.

Now, since we know that the weight *d* would just balance an equal weight, *g*, pulling directly upwards by the intervention of the pulley G; and that it just balances the weights *b* and *c*, acting in the directions A B, A C, we must infer, that the knot A is affected in the same manner by those two weights, or by the single weight *g*; and therefore, that two pressures, acting in the directions, and with the intensities, A B, A C, are equivalent to a single pressure having the direction and proportion of A D. In like manner, the pressures A B, A K, are equivalent to A H, which is equal and opposite to A C. Also A K and A C are equivalent to A I, which is equal and opposite to A B.

We shall consider this combination of pressures a little more particularly.

Figure 13.—Suppose an upright beam, pushed in the direction of its length by a load, B, and abutting on the ends of two beams, A C, A D, which are firmly resisted at their extreme points, C and D, which rest on two blocks, but are nowise joined to them: these two beams can only resist in the directions C A, D A; and therefore the pressures which they sustain from the beam, B A, are in the directions A C, A D. To know how much each sustains, produce B A to E, taking A E from a scale of equal parts, to represent the number of tons, or pounds, by which B A is pressed. Draw E F and E G parallel to A D and A C; then A F, measured on the same scale, will give the number of pounds by which A C is strained or crushed, and A G will give the strain on A D.

Here it deserves particular remark, that the length of A C or A D has no influence on the strain arising from the thrust of B A, while the directions remain the same. The effects, however, of this strain are modified by the length of the piece on which it is exerted. This strain compresses the beam, and will therefore compress a beam of double the length twice as much; though it may change the form of the assemblage. If A C, for example, be very much shorter than A D, it will be much less compressed: the line C A will turn about the centre, while D A will hardly change its position; and the angle C A D will grow more open, the point A sinking down. By thus changing shape, strains are often produced in places where there were none before, and frequently of the very worst kind, tending to break the beams across. The dotted lines of this figure show another position of the beam, A D′, which makes a material change, not only in the strain on A D′, but also in that on A C: both are much increased; A G being almost doubled, and A F four times greater than before. This addition was made to the figure to show what enormous strains may be produced by a very moderate force, A E, when it is exerted on a very obtuse angle.

Figures 14, 15, will assist the most uninstructed reader in conceiving how the very same strains, A F, A G, are laid on these beams, by a weight simply hanging from a billet resting on A, pressing hard on A D, and also leaning a little on A C; or by an upright piece, A E, joggled on two beams, A C, A D, and performing the office of an ordinary king-post.

Figure 15.—The proportion of these strains will be precisely the same, if everything be inverted, and each beam be drawn or pulled in the opposite direction. In the same way that we have substituted a rope and weight in *Figure* 14, or a king-post in *Figure* 15, for the loaded beam, B A, of *Figure* 13, the framing of *Figure* 16 might have been substituted, which is a very usual practice. In this framing, the batten, D A, is stretched by a force, A G, and the piece A C is compressed by a force, A F. It is evident that if a rope, or an iron rod, be fastened on at D, in place of the batten D A, the strains will be the same as before.

Figure 17.—By changing the form of this framing, the same strains are produced as in the disposition represented by the dotted lines in *Figure* 13. The strains on both the battens A D, A C, are now greatly increased.

Figure 18.—The same consequences result from an improper change of the position A C, where the strains on both are vastly increased. In short, the rule is general, that the more open we make the angle against which the push is exerted, the greater will be the strains on the struts or ties forming the sides of the angle.

The reader may not readily conceive the piece A C, of *Figure* 18, as sustaining a compression; for the weight B appears to hang from A C as much as from A D. But his doubts will be removed by considering whether he could employ a rope in place of A C; which he cannot; but A D may be exchanged for a rope. A C is therefore a strut, and not a tie.

Figure 19.—A D is again a strut, butting on the block D; A C is a tie; and the batten A C may be replaced by a rope. While A D is compressed by the force A G, A C is stretched by the force A F. Give A C the position represented by the dotted lines, the compression of A D will be A G′; while the force stretching A C′ will be A F′; both much greater than before. This disposition is analogous to *Figure* 18, and to the dotted lines in *Figure* 13. Nor will the young artist have any doubt of A C′ being on the stretch, if he consider whether A D can be replaced by a rope, which it cannot, but A C, may; and it is therefore not compressed, but stretched.

Figure 20.—All the three pieces, A C, A D, and A B, are ties on the stretch. This is the complete inversion of *Figure* 13; and the dotted position of A C′ induces the same changes in the forces A F′, A G′, as in that figure.

All calculations about the strength of carpentry are reducible to this case; for when more ties, or braces, meet in a point (a thing that rarely happens), they are to be reduced to three, by substituting for any two the force resulting from their combination, and combining this with another; and so on.

The young artist must be particularly careful not to mistake the kind of strain exerted on any piece of the framing, and suppose a piece to be a brace which is really a tie. It is very easy to avoid all mistakes in this matter by the following rule, which has no exception.

Take notice of the direction wherein the piece acts that produces the strain. Draw a line in that direction from the point on which the strain is exerted; and let its length (measured on some scale of equal parts) express the magnitude of this action in pounds, hundreds, or tons. From its remote extremity, draw lines parallel to the pieces on which the strain is exerted. The line parallel to one piece will necessarily cut the other, or its direction produced; if it cut the piece itself, that piece is compressed by the strain, and it is performing the office of a strut, or brace: if it cut its direction produced, the piece is stretched, and it is a tie. In short, the strains on the pieces A C, A D, are to be estimated in the direction of the points F and G from the strained point A. Thus, in *Figure* 13, the upright piece, B A, loaded with the weight B, presses the point A in the direction A E; so does the rope, A B, in the other figures, or the batten A B, in *Figure* 15.

In general, if the straining piece be within the angle formed by the pieces which are strained, the strains sustained by them are of the opposite kind to that which it exerts. If it be pushing, they are drawing; but if it be within the angle formed by their directions produced, the strains sustained by them are of the same kind. All the three are either drawing or pressing. If the straining piece lie within

the angle formed by one piece and the produced direction of the other, its own strain, whether compression or extension, is of the same kind with that of the most remote of the other two, and opposite to that of the nearest. Thus, in *Figure* 19, where A B is drawing, the remote piece, A C, is also drawing, while A D is pushing or resisting compression.

In these calculations the resistance of joints has no share; and they must not be supposed to exert any force which tends to prevent the angles from changing. The joints are supposed to be perfectly flexible, or like compass joints; the pin of which only keeps the pieces together when one or more of the pieces draws or pulls; of which description the carpenter must always suppose all joints to be, when he calculates the thrusts and draughts of the different pieces of his frames. The strains on joints, and their power to produce or balance them, are of a different kind, and require a very different examination.

Seeing that the angles which the pieces make with each other are of such importance to the magnitude and the proportion of the excited strains, it is proper to find out some way of readily and compendiously conceiving and expressing this analogy.

First, in general, the strain on any piece is proportional to the straining force.

Secondly, the strain on any piece, A C, is proportional to the sine of the angle which the straining force makes with the other piece directly, and to the sine of the angle which the pieces make with each other inversely.

For it is plain that the three pressures, A E, A F, and A G, which are exerted at the point A, are in the proportion of the lines A E, A F, and F E (because F E is equal to A G). But because the sides of a triangle are proportional to the sines of the opposite angles, the strains are proportional to the sines of the angles A F E, A E F, and F A E. But the sine of A F E is the same with the sine of the angle C A D, which the two pieces, A C and A D, make with each other; and the sine of A E F is the same with the sine of E A D, which the straining piece B A makes with the piece A C. Therefore we have this analogy: sine C A D: sine E A D = A E: A F and $AF = AE \times \frac{\text{sine E A D}}{\text{sine C A D}}$. Now, the sines of angles are most conveniently conceived as decimal fractions of the radius, which is considered as unity. Thus sine 30° is the same thing with 0.5 or $\frac{1}{2}$; and so of others. Therefore, to have the strain on A C, arising from any load, A E, acting in the direction A E, multiply A E by the sine of E A D, and divide the product by the sine of C A D.

This rule shows how great the strains must be when the angle C A D becomes very open, approaching to 180 degrees. But when the angle C A D becomes very small, its sine (which is our divisor) is also very small; and we should expect a very great quotient in this case also. But we must observe, that in this case the sine of E A D is also very small: and this is our multiplier. In such a case the quotient cannot exceed unity.

But it is unnecessary to consider the calculation by the tables of sines more particularly. The angles are seldom known otherwise than by drawing the figure of the frame of carpentry. In this case we can always obtain the measures of the strains from the same scale with equal accuracy, by drawing the parallelogram A F E G.

Hitherto we have considered the strains excited at A only, as they affect the pieces on which they are exerted. But the pieces, in order to sustain, or be subject to, any strain, must be supported at their ends C and D; and we may consider them as mere intermediums, by which these strains are made to act on the points of support; therefore A F and A G are also measures of the forces which press or pull at C and D. The supports to be found for these points may be infinitely various; but we shall attend only to such as depend on the framing itself.

Figure 21 is a structure which very frequently occurs, where one beam, B A, is strongly pressed to the end of another, A D, which latter is prevented from yielding, as well because it lies on a third, as because its end, D, is hindered from sliding backwards. It is indifferent from what this pressure arises: we have represented it as owing to a weight hung at B, while B is withheld from yielding by a rod or rope hooked to the wall. The beam A D may be supposed at full liberty to exert all its pressure on D, as if it were supported on rollers lodged in the beam H D; but the loaded beam B A presses both on the beam A D and on H D. We wish only to know what strain is borne by A D.

All bodies act on each other in the direction perpendicular to their touching surfaces; therefore the support given by H D is in a direction perpendicular to it. We may therefore supply its place at A by a beam, A C, perpendicular to H D, and firmly supported at C. In this case, therefore, we may take A E, as before, to represent the pressure exerted by the loaded beam, and draw E G perpendicular to A D, and E F parallel to it, meeting the perpendicular A C in F. Then A G is the strain compressing A D, and the pressure on the beam H D.

It may be thought, that since we assume as a principle that the mutual pressures of solid bodies are exerted perpendicular to their touching surfaces, this balance of pressures, in framings of timbers, depends on the directions of their butting joints; but it does not, as will readily appear by considering the present case. Let the joint or abutment of the two pieces B A, A D, be mitred in the usual manner, in the direction *f* A *f'*. Therefore, if A *e* be drawn perpendicular to A *f*, it will be the direction of the actual pressure exerted by the loaded beam, B A, on the beam A D. But the reaction of A D, in the opposite direction A *t*, will not balance the pressure of B A; because it is not in the direction precisely opposite. B A will therefore slide along the joint, and press on the beam H D. A E represents the load on the mitre joint A. Draw E *e* perpendicular to A *e*, and E *f* parallel to it. The pressure A E will be balanced by the reactions *e* A and *f* A: or, the pressure A E produces the pressures A *e* and A *f*; of which A *f* must be resisted by the beam H D, and A *e* by the beam A D. The pressure A *f* not being perpendicular to H D, cannot be fully resisted by it; because, by our assumed principle, it reacts only in a direction perpendicular to its surface. Therefore, draw *f k*, *f i* parallel to H D, and perpendicular to it. The pressure A *f* will be resisted by H D with the force *p* A; but there is required another force, *i* A, to prevent the beam B A from slipping outwards. This must be furnished by the reaction of the beam D A. In like manner the other force, A *e*, cannot be fully resisted by the beam A D, or rather by the prop D, acting by the intervention of the beam; for the action of that prop is exerted through the beam in the direction D A. The beam A D, therefore, is pressed to the beam H D, by the force A *e* as well as by A *f*. To find what this pressure on H D is, draw *e g* perpendicular to H D, and *e o* parallel to it, cutting E G in *r*. The forces *g* A and *o* A will resist, and balance A *e*.

Thus we see, that the two forces, A *e* and A *f*, which are equivalent to A E, are equivalent also to A *k*, A *i*, A *o*, and A *g*. But because A *f* and *e* E are equal and parallel, and E *r* and *f i* are also parallel, as also *e r* and *f k*, it is evident that *i f* is equal to *r* E, or to *o* F, and *i* A is equal to *r e*, or to G *g*. Therefore the four forces A *g*, A *o*, A *k*, A *i* are equal to A G

and A F. Therefore A G is the compression of the beam A D, or the force pressing it on D, and A F is the force pressing it on the beam H D. The proportion of these pressures, therefore, s not affected by the form of the joint.

This remark is important; for many carpenters think the form and direction of the butting joint of great importance; and even the theorist, by not prosecuting the general principle through all its consequences, may be led into an error. The form of the joint is of no importance, in as far as it affects the strains in the direction of the beams; but it is often of great consequence in respect to its own firmness, and the effect it may have in bruising the piece on which it acts, or being crippled by it.

The same compression of A B, and the same thrust on the point D, by the intervention of A D, will obtain, in whatever way the original pressure on the end A is produced. Thus, supposing that a cord is made fast at A, and pulled in the direction A E, and with the same force the beam A D will be equally compressed, and the prop D must re-act with the same force.

But it often happens, that the obliquity of the pressure on A D, instead of compressing, stretches it; and we desire to know what tension it sustains. Of this we have a familiar example in a common roof.

Figure 22.—Let the two rafters A C, A D, press on the tie-beam D C. We may suppose the whole weight to press vertically on the ridge A, as if a weight, B, were hung on there. We may represent this weight by the portion, A *b*, of the vertical or plumb line, intercepted between the ridge and the beam. Then drawing *b d* and *b g* parallel to A D and A C, A *g* and A *d* will represent the pressures on A C and A D. Produce A C till C H be equal to A *d*. The point C is forced out in this direction, and with a force represented by this line. As this force is not perpendicularly across the beam, it evidently stretches it; and this extending force must be withstood by an equal force pulling it in the opposite direction. This must arise from a similar oblique thrust of the opposite rafter on the other end, D. We concern ourselves only with this extension at present; but we see that the cohesion of the beam does nothing but supply the balance to the extending forces. It must still be supported externally, that it may resist, and, by resisting obliquely, be stretched. The points C and D are supported on the walls, which they press in the directions C K and D O, parallel to A *b*. If we draw H K parallel to D C, and H I parallel to C K (that is, to A *b*), meeting D C produced in I, it follows, from the composition of forces, that the point C would be supported by the two forces K C and I C. In like manner, making D N = A *g*, and completing the parallelogram D M N O, the point D would be supported by the forces O D and M D. If we draw *g c* and *d k* parallel to D C, it is plain that they are equal to N O and C I; while A *c* and A *k* are equal to D O and C K, and A *b* is equal to the sum of D O and C K (because it is equal to A *c* + A *k*). The weight of the roof is equal to its vertical pressure on the walls.

Thus we see, that while a pressure on A, in the direction A *b*, produces the strains A *d* and A *g*, on the pieces A C and A D, it also excites a strain, C I or D M, in the piece D C. And this completes the mechanism of a frame; which derives all its efficacy from the triangles of which it is composed, as will appear more clearly as we proceed.

The consideration of the strains on the two pieces A D and A C, by the action of a force at A, only showed them as the means of propagating the same strains in their own direction to the points of support. But, by adding the strains exerted in D C, the frame becomes an intermedium, by which exertions may be made on other bodies, in certain directions and proportions; so that this frame may become part of a more complicated one, and, as it were, an element of its constitution. The similarity of triangles gives the following analogies:

D O : D M = A *b* : *b* D
C I, or D M : C K = C *b* : A *b*
Therefore D O : C K = C *b* : *b* D.

Or, the pressures on the points C and D, in the direction of the straining force A *b*, are reciprocally proportional to the portions of D C intercepted by A *b*.

Also, A *b* = D O + C K, we have
A *b* : C K = C *b* + *b* D (or C D) : *b* D, and
A *b* : D O = C D : *b* C.

In general, any two of the three parallel forces, A *b*, D O, C K, are to each other in the reciprocal proportion of the parts of C D, intercepted between their directions and the direction of the third.

And this explains a still more important office of the frame A D C. If one of the points, such as D, be supported, an external power acting at A, in the direction A *b*, and with an intensity which may be measured by A *b*, may be set in equilibrio with another acting at C, in the direction C L, opposite to C K, or A *b*, and with an intensity represented by C K: for since the pressure C H is partly withstood by the force I C, or the firmness of the beam D C supported at E, the force K C will complete the balance. When we do not attend to the support at D, we conceive the force A *b* to be balanced by K C, or K C to be balanced by A *b*. And, in like manner, we may neglect the support or force acting at A, and consider the force D O as balanced by C K.

Thus the frame becomes a lever, and we are able to trace the interior mechanical procedure which gives it its efficacy.

The strains or pressures A *b*, D O, and C K, not being in the directions of the beams, may be called *transverse*. We see that by their means a frame of carpentry may be considered as a solid body: but the example is too limited for explaining the efficacy which may be given to such constructions. We shall therefore give a general proposition, which will more distinctly explain the procedure of nature, and enable us to trace the strains as they are propagated through all the parts of the most complicated framing, finally producing the exertion of its most distant points.

Figure 23.—Let the strong lines A B C D represent a frame of carpentry. Suppose it is to be pulled at the point A by a force acting in the direction A E, but that it rests on a fixed point, C, and that the other extreme point, B, is held back by a power which resists in the direction B F: it is required to determine the proportion of the strains excited in its different parts, the proportion of the external pressures at A and B, and the pressure which is produced on the obstacle or fulcrum C.

It is evident that each of the external forces at A and B tend one way, or to one side of the frame; that each would cause it to turn round C, if the other did not prevent it; and that, notwithstanding their action, if it turned neither way, the forces in actual exertion would be in equilibrio by the intervention of the frame. It is no less evident that these forces concur in pressing the frame on the prop C. Therefore, if the piece C D were away, and if the joints C and D be perfectly flexible, the pieces C A, C B, would be turned round the prop C, and the pieces A D, D B, would also turn with them, and the whole frame change its form. The power at A presses its end against the prop; and in doing this, it puts the bar A D on the stretch, and also the bar D B. Their places might therefore be supplied by cords or metal wires. Hence it is evident that D C is compressed, as is also A C: and,

for the same reason, C B is also in a state of compression: for either A or B may be considered as the point that is impelled or withheld. Therefore D A and D B are stretched, and are resisting with attractive forces. D C and C B are compressed, and are resisting with repulsive forces. D B is also acting with repulsive forces, being compressed in like manner: and thus the support of the prop, combined with the firmness of D C, puts the frame A D B C into the condition of the two frames in *Figure* 18 and *Figure* 19. Therefore the external force at A is really in equilibrio with an attracting force acting in the direction A D, and a repulsive force acting in the direction A K. And since all the connecting forces are mutual and equal, the point D is pulled or drawn in the direction D A. The condition of the point B is similar to that of A, and D is also drawn in the direction D B. Thus the point D, being urged by the forces in the directions D A and D B, presses the beam D C on the prop, and the prop resists in the opposite direction. Therefore the line D C is the diagonal of the parallelogram, whose sides have the proportion of the forces which connect D with A and B. This is the principle on which the rest of our investigation proceeds. We may take D C as the representation and measure of their joint effect. Therefore draw C H, C G, parallel to D A, D B. Draw H L, G O, parallel to C A C B, cutting A E, B F, in L and O, and cutting D A, D B, in I and M. Complete the parallelograms I L K A, M O N B; then D G and A I are the equal and opposite forces which connect A and D; for G D = C H, = A I. In like manner D H and B M are the forces which connect D and B.

The external force at A is in immediate equilibrio with the combined forces connecting A with D and with C. A I is one of them; therefore A K is the other; and A L is the compound force with which the external force at A is in immediate equilibrium. This external force is therefore equal and opposite to A L. In like manner, the external force at B is equal and opposite to B O; and A L is to B O as the external force at A to the external force at B. The prop C resists with forces equal to those which are propagated to it from the points D, A, and C. Therefore it resists with forces C H, C G, equal and opposite to D G, D H; and it resists the compressions K A, N B, with equal and opposite forces C *p*, C *n*. Draw *p b*, *n o*, parallel to A D, B D, and draw C *b* Q, C O P: it is plain that *p* C H *b* is a parallelogram equal to K A I L, and that C *b* is equal to A L. In like manner, C *o* is equal to B O. Now the forces C *p*, C H, exerted by the prop, compose the force C *b* and C *n*, C G compose the force C *o*. These two forces C *b*, C *o*, are equal and parallel to A L and B O; and therefore they are equal and opposite to the external forces acting at A and B. But they are (primitively) equal and opposite to the pressures (or at least the compounds of the pressures) exerted on the prop, by the forces propagated to C from A D, and B. Therefore the pressures exerted on the prop are the same as if the external forces were applied there in the same directions as they are applied to A and B. Now if we make C *v*, C *z*, equal to C *b* and C *o*, and complete the parallelogram C *v* Y *z*; it is plain that the force Y C is in equilibrio with *b* C and *o* C. Therefore the pressures at A, C, and B, are such as would balance if applied to one point.

Lastly, in order to determine their proportions, draw C S and C R perpendicular to D A and D B. Also draw A *d*, B *f* pependicular to C Q and C P; and draw C *g*, C *i* perpendicular to A E, B F.

The triangles C P R and B P *f* are similar, having a common angle, P, and a right angle at R and *f*. In like manner the triangles C Q S and A Q *d* are similar. Also the triangles C H R, C G S, are similar by reason of the equal angles at H and G, and the right angles at R and S. Hence we obtain the following analogies:

C *o* : C P = *o n* : P B = C G : P B
C P : C R = P B : *f* B
C R : C S = C H : C G
C S : C Q = A *d* : A Q
C Q : C *b* = A Q : *p b* : L K = A Q : C H

Therefore, by equality,

C *o* : C *b* = A *d* : *f* B
or, B O : A L = C *g* : C *i*

That is, the external forces are reciprocally proportional to the perpendiculars drawn from the prop on the lines of their direction.

This proposition is fertile in consequences, and furnishes many useful instructions to the artist. The strains L A, O B, C Y, that are excited, occur in many, if not in all framings of carpentry, whether for edifices or engines, and are the sources of their efficacy. It is also evident, that the doctrine of the transverse strength of timber is contained in this proposition; for every piece of timber may be considered as an assemblage of parts, connected by forces acting in the direction of the lines which join the strained points on the matter lying between those points, and also act on the rest of the matter, exciting those lateral forces which produce the inflexibility of the whole. Thus it appears that this proposition contains the principles which direct the artist to frame the most powerful levers; to secure uprights by shores or braces, or by ties and ropes; to secure scaffoldings for the erection of spires, and many other most delicate problems of his art. He also learns, from this proposition, how to ascertain the strains that are produced, without his intention, by pieces which he intended for other offices, and which, by their transverse action, put his work in hazard. In short, this proposition is the key to the science of his art.

There is a proposition which has been called in question by several very intelligent persons; and they say that Belidor has demonstrated, in his *Science des Ingeneurs*, that a beam firmly fixed at both ends is not twice as strong as when simply lying on the props, and that its strength is increased only in the proportion of 2 to 3; and they support this determination by a list of experiments recited by Belidor, which agree precisely with it. Belidor also says, that Pitot had the same results in his experiments. These are respectable authorities: but Belidor's reasoning is anything but demonstration; and his experiments are described in such an imperfect manner, that we cannot build much on them. It is not said in what manner the battens were secured at the ends, any farther than that it was by *chevalets*. If by this word is meant a *trestle*, we cannot conceive how they were employed; but we see this term sometimes used for a *wedge*, or *key*. If the battens were wedged in the holes, their resistance to fracture may be made what we please: they may be loose, and therefore resist little more than when simply laid on the props. They may be (and probably were) wedged very fast, and bruised or crippled.

Figure 24.—Let L M be a long beam divided into six equal parts, in the points D, B, A, C, E, and firmly supported at L, B, C, M; let it be cut through at A, and have compass joints at B and C; let F B, G C, be two equal uprights, resting on B and C, but without any connection; let A H be a similar and equal piece, to be occasionally applied at the seam A; then extend a thread, or wire, A G E, over the piece G C, and made fast at A, G, and E; do the same on the other side of A. Now, if a weight be laid on at A, the wires A F D, A G E, will be strained, and may be broken. In the instant of fracture, we may suppose their strains to be represented by A *f* and A *g*. Complete the parallelogram, and A *a* is the magnitude of the

weight. It is plain that nothing is concerned here but the cohesion of the wires; for the beam is sawn through at A, and its parts are perfectly moveable round B and C.

Instead of this process, apply the piece A H below A, and keep it there by straining the same wire, B H C, over it: lay on a weight, which must press down the ends of B A and C A, and cause the piece A H to strain the wire B H C. In the instant of fracture of the same wire, its resistances, H *b* and H *c* must be equal to A *f* and A *g*, and the weight *h* H, which breaks them, must be equal to A *a*.

Lastly, employ all the three pieces, F B, A H, G C, with the same wire attached as before. There can be no doubt but that the weight which breaks all the four wires must be = *a* A + *h* H, or twice A *a*.

The reader cannot but see that the wires perform the very same office with the fibres of an entire beam, L M, held fast in the four holes, D B C, and E, of some upright posts.

In the experiments for verifying this, by breaking slender bars of fine deal, we get complete demonstration, by measuring the curvatures produced in the parts of the beam thus held down, and comparing them with the curvature of a beam simply laid on the props B and C; and there are many curious inferences to be made from these observations.

We may observe, by the way, that we learn from this case, that purlins are able to carry twice the load when notched into the rafters, that they carry when mortised into them, which is the most usual manner of framing them. So would the binding joists of floors; but this would double the thickness of the flooring. But this method should be followed in every possible case, such as bres-summers, lintels over several pillars, &c. These should never be cut off and mortised into the sides of every upright; numberless cases will occur which show the importance of the maxim.

We here remark, that the proportion of the spaces B C and C M, or B C and L B, has a very sensible effect on the strength of the beam B C; but we have not yet satisfied our minds as to the *rationale* of this effect. It is undoubtedly connected with the serpentine form of the curve, of the beam before fracture. This should be attended to in the construction of the springs of carriages. These are frequently supported at a middle point (and it is an excellent practice), and there is a certain proportion which will give the easiest motion to the body of the carriage. We also think that it is connected with that deviation from the best theory observable in Buffon's experiments on various lengths of the same scantling. The force of the beams diminished much more than in the inverse proportion of their lengths.

We have seen that it depends entirely on the position of the pieces in respect of their points of ultimate support, and of the direction of the external force which produces the strains, whether any particular piece is in a state of extension or of compression. The knowledge of this circumstance may greatly influence us in the choice of the construction. In many cases we may substitute slender iron rods for massive beams, when the piece is to act the part of a tie. But we must not invert this disposition; for when a piece of timber acts as a strut, and is in a state of compression, it is next to certain that it is not equally compressible in its opposite sides through the whole length of the piece, and that the compressing force on the abutting joint is not acting in the most equable manner all over the joint. A very trifling inequality in either of these circumstances (especially in the first) will compress the beam more on one side than on the other. This cannot be without the beam's bending, and becoming concave on that side on which it is most compressed. When this happens, the frame is in danger of being crushed, and soon going to ruin. It is therefore indispensably necessary to make use of beams in all cases where struts are required of considerable length, rather than of metal rods of slender dimensions, unless in situations where we can effectually prevent their bending, as in trussing a girder internally, where a cast-iron strut may be firmly cased in it, so as not to bend in the smallest degree. In cases where the pressures are enormous, as in the very oblique struts of a centre, or arch frame, we must be particularly cautious to do nothing which can facilitate the compression of either side. No mortises should be cut near to one side; no lateral pressures, even the slightest, should be allowed to touch it. We have seen a pillar of fir, 12 inches long and 1 in section, when loaded with three tons, snap in an instant when pressed on one side by 16 pounds, while another bore 4½ tons without hurt, because it was enclosed (loosely) in a stout pipe of iron.

In such cases of enormous compression, it is of great importance that the compressing force bear equally on the whole abutting surface. The German carpenters are accustomed to put a plate of lead over the joint. This prevents, in some measure, the penetration of the end fibres. M. Perronet, the celebrated French architect, formed his abutments into arches of circles, the centre of which was the remote end of the strut. By this contrivance the unavoidable change of form of the triangle made no partial bearing upon either angle of the abutment. This always has a tendency to splinter off the heel of the beam where it presses strongest. It is a very judicious practice.

When circumstances allow it, we should rather employ ties than struts, for securing a beam against lateral strains. When an upright pillar, such as a flag-staff, a mast, or the uprights of a very tall scaffolding, are to be shored up, the dependence is more certain on those braces that are stretched by the strain than on those which are compressed. The scaffolding of the iron bridge near Sunderland had some ties very judiciously disposed, and others with less judgment.

Figure 25.—1. When a beam, A B, is firmly fixed at the end, A, and a straining force acts perpendicularly to its length at any point, B, the strain occasioned at any section, C, between B and A, is proportional to C B, and may therefore be represented by the product $w \times C B$; that is, by the product of the number of tons, pounds, &c. which measure the straining force, and the number of feet, inches, &c. contained in C B. As the loads on a beam are easily conceived, we shall substitute this for any other straining force.

2. If the strain or load be uniformly distributed along any part of the beam lying beyond C (that is, farther from A), the strain at C is the same as if the load were all collected at the middle point of that part; for that point is the centre of gravity of the load.

Figure 26.—3. The strain on any section, D, of a beam A B, resting freely on two props, A and B, is $w \times \frac{A D \times D B}{A B}$.

4. The strain on the middle point, by a force applied there, is one-fourth of the strain which the same force would produce, if applied to one end of a beam of the same length having the other end fixed.

5. The strain of any section, C, of a beam resting on two props, A and B, occasioned by a force applied perpendicularly to another point, D, is proportional to the rectangle of the exterior segments, or is equal to $w \times \frac{A C \times D B}{A C}$. Therefore the strain at C, occasioned by the pressure on D, is the same with the strain at D, occasioned by the same pressure on C.

6. The strain on any section, D, occasioned by a load uni

formly diffused over any part, E F, is the same as if the two parts, E D, D F, of the load were collected at the middle points, *e* and *f*. Therefore the strain on any part, D, occasioned by a load uniformly distributed over the whole beam, is one-half of the strain that is produced when the same load is laid on at D; and the strain on the middle point, C, occasioned by a load uniformly distributed over the whole beam, is the same which half that load would produce if laid on at C.

Figure 24.—7. A beam supported at both ends on two props, B and C, will carry twice as much when the ends beyond the props are kept from rising, as it will carry when it rests loosely on the props.

8. Lastly, the transverse strain on any section, occasioned by a force applied obliquely, is diminished in the proportion of the sine of the angle which the direction of the force makes with the beam. Thus, if it be inclined to it in an angle of thirty degrees, the strain is one-half of the strain occasioned by the same force acting perpendicularly.

On the other hand, the *relative strength* of a beam, or its power in any particular section to resist any transverse strain, is proportional to the absolute cohesion of the section directly to the distance of its centre of effort from the axis of fracture directly, and to the distance from the strained point inversely.

Thus, in a rectangular section of the beam, of which b is the breadth, d the depth (that is, the dimension in the direction of the straining force), measured in inches, and f the number of pounds which one square inch will just support without being torn asunder, we must have $f \times b \times d^2$, proportional to $w \times$ C B. Or, $f \times b \times d^2$, multiplied by some number, m, depending on the nature of the timber, must be equal to $w \times$ C B. Or, in the case of the section, C, of *Figure* 46, that is strained by the force, w, applied at D, we must have $m \times f\, b\, d^2 = w \times \frac{\text{A C} \times \text{D B}}{\text{A B}}$. Thus, if the beam is of sound oak, m is very nearly $= \frac{1}{9}$. Therefore we have $\frac{f\, b\, d^2}{9} = w \times \frac{\text{A C} \times \text{C B}}{\text{A B}}$. Hence we can tell the precise force, w, which any section, C, can just resist when that force is applied in any way whatever. For the above-mentioned formula gives $w = \frac{f\, b\, d^2}{9 \text{ C B}}$, for the case represented by *Figure* 25. But the case represented in *Figure* 26 having the straining force applied at D, gives the strain at C $(= w)$ $= f \times \frac{b\, d^2 \times \text{A B}}{9 \text{ A C} \times \text{C B}}$.

Example.—Let an oak beam, four inches square, rest freely on the props A and B, seven feet apart, or 84 inches. What weight will it just support at its middle point, C, on the supposition that a square inch rod will just carry 16,000 pounds, pulling it asunder?

The formula becomes $w = \frac{16000 \times 4 \times 16 \times 84}{9 \times 42 \times 42}$ or $w = \frac{86016000}{15876} = 5418$ pounds. This is very near what was employed in Buffon's experiment, which was 5312.

Had the straining force acted on a point, D, half way between C and B, the force sufficient to break the beam at C would be equal to $\frac{16000 \times 4 \times 16 \times 84}{9 \times 42 \times 21} = 10836$ lbs.

Had the beam been sound red fir, we must have taken $f = 10{,}000$ nearly, and m nearly 8; for although fir be less cohesive than oak in the proportion of 5 to 8 nearly, it is less compressible, and its axis of fracture is therefore nearer to the concave side.

Having considered at sufficient length the strains of different kinds which arise from the form of the parts of a frame of carpentry, and the direction of the external forces which act on it, whether considered as impelling or as supporting its different parts, we must now proceed to consider the means by which this form is to be secured, and the connections by which those strains are excited and communicated.

The joinings practised in carpentry are almost infinitely various, and each has advantages which make it preferable in some circumstances. Many varieties are employed merely to please the eye. We do not concern ourselves with these, nor shall we consider those which are only employed in connecting small works, and can never appear on a great scale; yet, even in some of these, the skill of the carpenter may be discovered by his choice; for, in all cases, it is wise to make every part of his work, even in the smallest details, as strong as the materials will admit. He will be particularly attentive to the changes which will necessarily happen by the shrinking of timber as it dries, and will consider what dimensions of his framings will be affected by this, and what will not; and will then dispose the pieces which are less essential to the strength of the whole, in such a manner that their tendency to shrink shall be in the same direction with the shrinking of the whole framing. If he do otherwise, the seams will widen, and parts will be split asunder. He will dispose his boardings in such a manner as to contribute to the stiffness of the whole, avoiding at the same time the giving them positions which will produce lateral strains on truss-beams which bear great pressures: recollecting, that although a single board has little force, yet many united have a great deal, and may frequently perform the office of very powerful struts.

Our limits confine us to the joinings which are most essential for connecting the parts of a single piece of a frame when it cannot be formed of one beam, either for want of the necessary thickness or length; and the joints for connecting the different sides of a trussed frame.

Much ingenuity and contrivance has been bestowed on the manner of building up a great beam of many thicknesses, and many singular methods are practised, as great nostrums, by different artists; but when we consider the manner in which the cohesion of the fibres performs its office, we shall clearly see that the simplest are equally effectual with the most refined, and that they are less apt to lead us into false notions of the strength of the assemblage.

Thus, were it required to build up a beam for a great lever or a girder, so that it may act nearly as a beam of the same size of one log; it may either be done by plain joggling, as in *Figure* 27, A, or by scarfing, as at B or C. If it is to act as a lever, having the gudgeon on the lower side, we believe that most artists will prefer the form B and C: at least this has been the case with nine-tenths of those to whom we have proposed the question. The best informed only hesitated; but the ordinary artists were all confident in its superiority: and we found their views of the matter very coincident. They considered the upper piece as grasping the lower in its hooks; and several imagined that, by driving the one very tight on the other, the beam would be stronger than an entire log: but if we attend carefully to the internal procedure in the loaded lever, we shall find the upper one clearly the strongest. If they are formed of equal logs, the upper one is thicker than the other by the depth of the joggling or scarfing, which we suppose to be the same in both; consequently, if the cohesion

of the fibres in the intervals is able to bring the uppermost filaments into full action, the form A is stronger than B, in the proportion of the greater distance of the upper filaments from the axis of the fracture: this may be greater than the difference of the thickness, if the wood is very compressible. If the gudgeon be in the middle, the effect, both of the joggles and the scarfings, is considerably diminished; and if it is on the upper side, the scarfings act in a very different way. In this situation, if the loads on the arms are also applied to the upper side, the joggled beam is still more superior to the scarfed one. This will be best understood by resolving it in imagination into a trussed frame. But when a gudgeon is thus put on that side of the lever which grows convex by the strain, it is usual to connect it with the rest by a powerful strap, which embraces the beam, and causes the opposite point to become the resisting point. This greatly changes the internal actions of the filaments, and, in some measure, brings it into the same state as the first, with the gudgeon below. Were it possible to have the gudgeon on the upper side, and to bring the whole into action without a strap, it would be the strongest of all; because, in general, the resistance to compression is greater than to extension. In every situation the joggled beam has the advantage; and it is the easiest executed. We may frequently gain a considerable accession of strength by this building up of a beam; especially if the part which is stretched by the strain be of oak, and the other part of fir. Fir being so much superior to oak as a pillar (if Musschenbroek's experiments may be confided in), and oak so much preferable as a tie, this construction seems to unite both advantages. But we shall see much better methods of making powerful levers, girders, &c. by trussing.

Observe, that the efficacy of both methods depends entirely on the difficulty of causing the piece between the cross joints to slide along the timber to which it adheres. Therefore, if this be moderate, it is wrong to make the notches deep; for as soon as they are so deep that their ends have a force sufficient to push the slice along the line of junction, nothing is gained by making them deeper; and this requires a greater expenditure of timber.

Scarfings are frequently made oblique, as in *Figure* 28, but we imagine that this is a bad practice. It begins to yield at the point, where the wood is *crippled* and *splintered* off, or at least bruised out a little: as the pressure increases, this part, by squeezing broader, causes the solid parts to rise a little upwards, and gives them some tendency, not only to push their antagonists along the base, but even to tear them up a little. For similar reasons, we disapprove of the favourite practice of many artists, to make the angles of their scarfings acute, as in *Figure* 29. This often causes the two pieces to tear each other up. The abutments should always be perpendicular to the directions of the pressures. Lest it should be forgotten in its proper place, we may extend this injunction also to the abutments of different pieces of a frame, and recommend it to the artist even to attend to the shrinking of the timbers by drying. When two timbers abut obliquely, the joint should be most full at the obtuse angle of the end; because, by drying, that angle grows more obtuse, and the beam would then be in danger of splintering off at the acute angle.

It is evident, that the nicest work is indispensably necessary in building up a beam. The parts must abut on each other completely, and the smallest play, or void, takes away the whole efficacy. It is usual to give the butting joints a small taper to one side of the beam, so that they may require moderate blows of a maul to force them in, and the joints may be perfectly close when the external surfaces are even on each side of the beam. But we must not exceed in the least degree; for a very taper wedge has great force; and if we have driven the pieces together by very heavy blows, we leave the whole in a state of violent strain, and the abutments are perhaps ready to splinter off by a small addition of pressure.

The most general reason for piecing a beam is to increase its length. This is frequently necessary, in order to procure tie-beams for very wide roofs. Two pieces must be scarfed together. Numberless are the modes of doing this; and almost every master carpenter has his favourite nostrum. Some of them are very ingenious: but here, as in other cases, the most simple are commonly the strongest. We do not imagine that any, the most ingenious, is equally strong with a tie consisting of two pieces of the same scantling laid over each other for a certain length, and firmly bolted together. We acknowledge that this will appear an artless and clumsy tie-beam; but we only say that it will be stronger than any that is more artificially made up of the same thickness of timber. This, we imagine, will appear sufficiently certain. The simplest and most obvious scarfing (after the one now mentioned) is that represented in *Figure* 30, No. 1 and 2. If considered merely as two pieces of wood joined, it is plain that, as a tie, it has but half the strength of an entire piece, supposing that the bolts (which are the only connections) are fast in their holes. No. 2 requires a bolt in the middle of the scarf, to give it that strength; and, in every other part, is weaker on one side or the other.

But the bolts are very apt to bend by the violent strain, and require to be strengthened by uniting their ends by iron plates; in which case it is no longer a wooden tie. The form of No. 1 is better adapted to the office of a pillar than No. 2; especially if its ends be formed in the manner shown in the elevation, No. 3. By the sally given to the ends, the scarf resists an effort to bend it in that direction. Besides, the form of No. 2 is unsuitable for a post; because the pieces, by sliding on each other by the pressure, are apt to splinter off the tongue which confines their extremity.

Figures 31 and 32, exhibit the most approved form of a scarf, whether for a tie or a post. The key represented in the middle is not essentially necessary: the two pieces might simply meet square there. This form, without a key, needs no bolts (although they strengthen it greatly); but if worked very true and close, and with square abutments, will hold together, and will resist bending in any direction. But the key is an ingenious and a very great improvement, and will force the parts together with perfect tightness. The same precaution must be observed that we mentioned on another occasion, not to produce a constant internal strain on the parts by over-driving the key. The form of *Figure* 31 is by far the best; because the triangle of 32 is much easier splintered off by the strain, or by the key, than the square wood of 31. It is far preferable for a post, for the reason given when speaking of *Figure* 30, No. 1 and 2. Both may be formed with a sally at the ends equal to the breadth of the key. In this shape, *Figure* 31 is vastly well suited for joining the parts of the long corner posts of spires and other wooden towers. *Figure* 31, No. 2, differs from No. 1 only by having three keys. The principle and longitudinal strength are the same. The long scarf of No. 2, tightened by the three keys, enables it to resist a bending much better.

None of these scarfed tie-beams can have more than one-third of the strength of an entire piece, unless with the assistance of iron plates; for if the key be made thinner than one-third, it has less than one-third of the fibres to pull by.

We are confident, therefore, that when the heads of the bolts are connected by plates, the simple form of *Figure* 30,

No. 1, is stronger than those more ingenious scarfings. It may be strengthened against lateral bendings by a little tongue, or by a sally; but it cannot have both.

The strongest of all methods of piecing a tie-beam would be to set the parts end to end, and grasp them between other pieces on each side, as in *Figure* 33. This is what the ship-carpenter calls *fishing* a beam; and is a frequent practice for occasional repairs. M. Perronet used it for the tie-beams, or stretchers, by which he connected the opposite feet of a centre, which was yielding to its load, and had pushed aside one of the piers above four inches. Six of these not only withstood a strain of 1,800 tons, but, by wedging behind them, he brought the feet of the truss 2½ inches nearer. The stretchers were 14 inches by 11, of sound oak, and could have withstood three times that strain. M. Perronet, fearing that the great length of the bolts employed to connect the beams of these stretchers would expose them to the risk of bending, scarfed the two side pieces into the middle piece. The scarfing was of the triangular kind (*trait de Jupiter*), and only an inch deep, each face being two feet long, and the bolt passed through close to the angle.

In piecing the pump rods, and other wooden stretchers of great engines, no dependence is had on scarfing; and the engineer connects everything by iron straps. But we doubt the propriety of this, at least in cases where the bulk of the wooden connection is not inconvenient.

These observations must suffice for the methods employed for connecting the parts of a beam; and we now proceed to consider what are more usually called *the joints* of a piece of carpentry.

Where the beams stand square with each other, and the strains are also square with the beams, and in the plane of the frame, the common mortise and tenon is the most perfect junction. A pin is generally put through both, in order to keep the pieces united, in opposition to any force which tends to part them. Every carpenter knows how to bore the hole for this pin, so that it shall draw the tenon tight into the mortise, and cause the shoulder to butt close, and make neat work; and he knows the risk of tearing out the bit of the tenon beyond the pin, if he draw it too much. We may just observe, that square holes and pins are much preferable to round ones for this purpose, bringing more of the wood into action, with less tendency to split it. The ship-carpenters have an ingenious method of making long wooden bolts, which do not pass completely through, take a very fast hold, though not nicely fitted to their holes, which they must not be, lest they should be crippled in driving. They call it *fox-tail wedging*. They stick into the point of the bolt a very thin wedge of hard wood, so as to project a proper distance: when this reaches the bottom of the hole by driving the bolt, it splits the end of it, and squeezes it hard to the side. This may be practised with advantage in carpentry. If the ends of the mortise are widened inwards, and a thin wedge be put into the head of the tenon, it will have the same effect, and make the joint equal to a dovetail. But this risks the splitting of the piece beyond the shoulder of the tenon, which would be unsightly. This may be avoided as follows:—Let the tenon, T, *Figure* 34, have two very thin wedges, *a* and *c*, stuck in near its angles, projecting equally: at a very small distance within these, put in two shorter wedges, *b*, *d*, and more within these, if necessary. In driving this tenon, the wedges *a* and *c* will take first, and split off a thin slice, which will easily bend without breaking. The wedges *b*, *d*, will act next, and have a similar effect, and the others in succession. The thickness of all the wedges taken together must be equal to the enlargement of the mortise toward the bottom.

The mortise in a girder for receiving the tenon of a binding joist of a floor should be as near the upper side as possible, because the girder becomes concave on that side by the strain. But as this exposes the tenon of the binding-joist to the risk of being torn off, we are obliged to mortise farther down. The form (*Figure* 35) generally given to this joint is extremely judicious. The sloping part *a b*, gives a very firm support to the additional bearing *c d*, without much weakening of the girder. This form should be copied in every case where the strain has a similar direction.

The joint that most of all demands the careful attention of the artist, is that which connects the ends of beams, one of which pushes the other very obliquely, putting it into a state of extension. The most familiar instance of this is the foot of a rafter pressing on the tie-beam, and thereby drawing it away from the other wall. When the direction is very oblique (in which case the extending strain is the greatest), it is difficult to give the foot of the rafter such a hold of the tie-beam as to bring many of its fibres into the proper action. There would be little difficulty if we could allow the end of the tie-beam to project to a small distance beyond the foot of the rafter; but, indeed, the dimensions which are given to tie-beams, for other reasons, are always sufficient to give enough of abutment when judiciously employed. Unfortunately, this joint is much exposed to failure by the effects of the weather. It is much exposed, and frequently perishes by rot, or becomes so soft and friable, that a very small force is sufficient, either for pulling the filaments out of the tie-beam, or for crushing them together. We are therefore obliged to secure it with particular attention, and to avail ourselves of every circumstance of construction.

One is naturally disposed to give the rafter a deep hold by a long tenon; but it has been frequently observed, in old roofs, that such tenons break off. Frequently they are observed to tear up the wood that is above them, and push their way through the end of the tie-beam. This, in all probability, arises from the first sagging of the roof, by the compression of the rafters and of the head of the king-post. The head of the rafter descends; the angle, with the tie-beam, is diminished by the rafter revolving round its step in the tie-beam. By this motion the heel, or inner angle of the rafter, becomes a fulcrum to a very long and powerful lever much loaded. The tenon is the other arm, very short, and being still fresh, it is therefore very powerful. It therefore forces up the wood that is above it, tearing it out from between the cheeks of the mortise, and then pushes it along. Carpenters have therefore given up long tenons, and give to the toe of the tenon a shape which abuts firmly, in the direction of the thrust, on the solid bottom of the mortise, which is well supported on the under side by the wall-plate. This form has the farther advantage of having no tendency to tear up the end of the mortise; and is represented in *Figure* 36. The tenon has a small portion, *a b*, cut perpendicular to the surface of the tie-beam, and the rest, *b c*, is perpendicular to the rafter.

But if the tenon be not sufficiently strong (and it is not so strong as the rafter, which is thought not to be stronger than is necessary), it will be crushed, and then the rafter will slide out along the surface of the beam. It is therefore necessary to call in the assistance of the whole rafter. It is in this distribution of the strain among the various abutting parts, that the varieties of joints and their merits chiefly consist. It would be endless to describe every nostrum, and we shall only mention a few that are most generally approved of.

The aim, in *Figure* 37, is to make the abutments exactly perpendicular to the thrusts. It does this very precisely; and the share which the tenon and the shoulder have of the whole

may be what we please, by the portion of the beam that we notch down. If the wall plate lie duly before the heel of the rafter, there is no risk of straining the tie across, or breaking it, because the thrust is made direct to that point where the beam is supported. The action is the same as against the joggle on the head or foot of a king-post. We have no doubt but that this is a very effectual joint. It is not, however, much practised. It is said that the sloping seam at the shoulder lodges water; but the great reason seems to be a secret notion that it weakens the tie-beam. If we consider the direction in which it acts as a tie, we must acknowledge that this form takes the best method for bringing the whole of it into action.

Figure 38 exhibits a form that is more general, but certainly worse. The part of the thrust that is not borne by the tenon acts obliquely on the joint of the shoulder, and gives the whole a tendency to rise up and slide outward.

The shoulder joint is sometimes formed like the dotted line, *a b c d e f g*, of *Figure* 38. This is much more agreeable to the true principle, and would be a very perfect method, were it not that the intervals, *b d* and *d f*, are so short that the little wooden triangles, *b c d*, *d e f*, will be easily pushed off their bases, *b d*, *d f*.

Figure 39 seems to have the most general approbation. It is the joint recommended by Price, (p. 7), and copied into all books of carpentry, as the true joint for a rafter foot. The visible shoulder-joint is flush with the upper surface of the tie-beam. The angle of the tenon at the tie nearly bisects the obtuse angle formed by the rafter and the beam, and is therefore somewhat oblique to the thrust. The inner shoulder, *a c*, is nearly perpendicular to *b d*. The lower angle of the tenon is cut off horizontally, as at *e d*.

Figure 40 is a section of the beam and rafter foot, showing the different shoulders.

We do not perceive the peculiar merit of this joint. The effect of the three oblique abutments *a b*, *a c*, *e d*, is undoubtedly to make the whole bear on the outer end of the mortise, and there is no other part of the tie-beam that makes immediate resistance. Its only advantage over a tenon extending in the direction of the thrust, is, that it will not tear up the wood above it. Had the inner shoulder had the form *e c i*, having its face, *i c*, perpendicular, it certainly would have acted more powerfully in stretching many filaments of the tie-beam, and would have had much less tendency to force out the end of the mortise. The little bit, *c i*, would have prevented the sliding upwards along *e c*. At any rate, the joint, *a b*, being flush with the beam, prevents any sensible abutment on the shoulder, *a c*.

Figure 39, No 2. is a simpler, and in our opinion a preferable, joint. We observe it practised by the most eminent carpenters, for all oblique thrusts; but it surely employs less of the cohesion of the tie-beam than might be used without weakening it, at least when it is supported on the other side by the wall-plate.

Figure 39, No. 3, is also much practised by the first carpenters.

Figure 41 is proposed by Mr. Nicholson, as preferable to *Figure* 39, No. 3, because the abutment of the inner part is better supported. This is certainly the case; but it supposes the whole rather to go to the bottom of the socket, and the beam to be thicker than the rafter. Some may think that this will weaken the beam too much, when it is no broader than the rafter is thick: in which case they think that it requires a deeper socket than Nicholson has given it. Perhaps the advantages of Nicholson's construction may be had by a joint like *Figure* 41, No. 2.

Whatever be the form of these butting joints, great care should be taken that all parts bear alike, and the artist will attend to the magnitude of the different surfaces. In the general compression, the greater surfaces will be less compressed, and the smaller will therefore change most. When all has settled, every part should be equally close. Because great logs are moved with difficulty, it is very troublesome to try the joint frequently, to see how the parts fit; therefore we must expect less accuracy in the interior parts. This should make us prefer those joints whose efficacy depends chiefly on the visible joint.

It appears from all that we have said on this subject, that a very small part of the cohesion of the tie-beams is sufficient for withstanding the horizontal thrust of a roof, even though very low pitched. If therefore no other use be made of the tie-beam, one much slenderer may be used, and blocks may be firmly fixed to the ends, on which the rafters might abut, as they do on the joggles on the head and foot of a king-post. Although a tie-beam has commonly floors or ceilings to carry, and sometimes the workshops and store-rooms of a theatre, and therefore requires a great scantling, yet there frequently occur in machines and engines very oblique stretches, which have no other office, and are generally made of dimensions quite inadequate to their situation, often containing ten times the necessary quantity of timber. It is therefore of importance to ascertain the most perfect manner of executing such a joint. We have directed the attention to the principles that are really concerned in the effect. In all hazardous cases, the carpenter calls in the assistance of iron straps; and they are frequently necessary, even in roofs, notwithstanding this superabundant strength of the tie-beams. But this is generally owing to the bad construction of the wooden joint, or to the failure of it by time. Straps will be considered in their place.

There need but little to be said of the joints at a joggle worked out of solid timber; they are not near so difficult as the last. When the size of a log will allow the joggle to receive the whole breadth of the abutting brace, it ought certainly to be made with a square shoulder; or, which is still better, an arch of a circle, having the other end of the brace for its centre. Indeed, this in general will not sensibly differ from a straight line perpendicular to the brace. By this circular form, the setting of the roof makes no change in the abutment; but when there is not sufficient stuff for this, we must avoid bevel joists at the shoulders, because these always tend to make the brace slide off. The brace, in *Figure* 42, must not be joined as at *a*, but as at *b*, or some equivalent manner.

When the very oblique action of one side of a frame of carpentry does not extend, but compress the piece on which it abuts, as in *Figure* 21, there is no difficulty in the joint. Indeed, a joining is unnecessary, and it is enough that the pieces abut on each other; and we have only to take care that the mutual pressure be equally borne by all the parts, and that it do not produce lateral pressures, which may cause one of the pieces to slide on the butting joint. A very slight mortise and tenon is sufficient at the joggle of a king-post, with a rafter or straining beam. It is best, in general, to make the butting plain, bisecting the angle formed by the sides, or else perpendicular to one of the pieces. In *Figure* 42, No. 2, where the straining beam, *a b*, cannot slip away from the pressure, the joint *a* is preferable to *b*, or indeed to any uneven joint, which never fails to produce very unequal pressures on the different parts, by which some are crippled, others are splintered off, &c.

When it is necessary to employ iron steps for strengthening a joint, a considerable attention is necessary, that we may place them properly. The first thing to be determined is the

direction of the strain. We must then resolve this strain into a strain parallel to each piece, and another perpendicular to it. Then the strap, which is to be made fast to any of the pieces, must be so fixed, that it shall resist in the direction parallel to the piece. Frequently this cannot be done; but we must come as near to it as we can. In such cases, we must suppose that the assemblage yields a little to the pressures which act on it. We must examine what change of shape a small yielding will produce. We must now see how this will affect the iron strap, which we have already supposed attached to the joint in some manner that we thought suitable. This settling will perhaps draw the pieces away from it, leaving it loose and unserviceable; (this frequently happens to the plates which are put to secure the obtuse angles of butting timbers, when their bolts are at some distance from the angles, especially when these plates are laid on the inside of the angles); or it may cause it to compress the pieces harder than before; in which case it is answering our intention. But it may be producing cross strains, which may break them; or it may be crippling them. We can hardly give any general rules; he will see the nature of the strap or stirrup by which the king-post carries the tie-beam. The strap that we observe most generally ill-placed is that which connects the foot of the rafter with the beam. It only binds down the rafter, but does not act against its horizontal thrust. It should be placed farther back on the beam, with a bolt through it, which will allow it to turn round. It should embrace the rafter almost horizontally near the foot, and should be notched square with the back of the rafter. Such a construction is represented in *Figure* 43. By moving round the eye-bolt it follows the rafter, and cannot pinch and cripple it, which it always does in its ordinary form. We are of opinion that straps which have eye-bolts in the very angles, and allow all motion round them, are, of all, the most perfect. A branched strap, such as may at once bind the king-post and the two braces which butt on its foot, will be more serviceable if it have a joint. When a roof warps, those branched steps frequently break the tenons, by affording a fulcrum in one of their bolts. An attentive and judicious artist will consider how the beams will act on such occasions, and will avoid giving rise to these great strains by levers. A skilful carpenter never employs many straps, considering them as auxiliaries foreign to his art, and subject to imperfections in workmanship, which he cannot discern nor amend.—*Supplement to the article Carpentry of the Encyclopædia Britannica, by Professor Robinson.*

The following part was written by Mr. Nicholson for the *Edinburgh Cyclopædia*, and is here inserted by permission of the editor.

A circular roof may be executed with timbers disposed in vertical planes, whether the ribs or rafters are convex, concave, or straight, without any tie between the rafters or ribs, even though the wall were ever so thin; provided that it be only sufficient to sustain the weight of the roof pressing vertically, by joining the wall-plate so as to form a complete ring, and by strutting the rafters in one or more horizontal courses, without danger of lateral pressure, or of the timbers being bent by the weight of the covering. The same cannot be done with the roof of a rectangular building, for single parallel rafters would not only obtain a concave curvature, but would thrust the walls outwards: hence the means of executing circular roofs with safety are simple; but those for straight-sided buildings are complex, and require much skill in contriving, according to the use that is to be made of the space between the rafters, which may be found necessary in rendering more lofty, or more elegant apartments, as in concave, or coved ceilings.

A polygonal roof, with a great number of sides, approaching very nearly to a circle, is stronger than one of fewer sides; the less the number of sides, the weaker will the roof be, and more liable to get out of order. A roof executed upon an equilateral and equiangular polygonal plan, is much stronger than one that is elongated. All circular roofs, for the same reason, are stronger than elliptical ones; the pressure in the former case being equally distributed round the wall-plate, which is therefore kept in an equal state of tension.

Trusses are strong frames of carpentry, resolved into two or a series of triangles, so as to make the truss act as a solid body, and thereby support certain weights, each at a given immoveable point, the truss itself being suspended from two such immoveable points. The trusses of roofs are constructed generally of a triangular form, and disposed equidistantly on the wall-plates, in parallel vertical planes, at right angles to the walls; the top of the opposite walls are the two points of suspension, and the weights supported by the truss at the immoveable points are horizontal pieces of timber, running transversely to the planes of the trusses: these horizontal pieces of timber support other equidistant pieces parallel to the upper sides of the trusses, and these last timbers support the covering, or the covering and timber-work, to which the covering is fixed. In a truss, some pieces of timber are in a state of tension, and some are in a state of compression; but a piece of timber which is neither extended nor compressed, is useless. A quadrilateral frame, so constructed that each two adjoining timbers, made moveable round a point at their intersection, may be put into an infinite number of forms, because the whole frame will be revolvable about the angles: but if any one of the angles be immoveable, the whole frame will also be so. Two pieces of timber forming an angle, and revolving round a point at their intersection, may be made immoveable by fastening each end of a bar to each leg, or by taking any two points in the bar, and fastening each point to each leg. Now, if a force be applied at any of the three angular points, the frame will be immoveable, but of the two legs which form the angle, the one will be in a state of tension, and the other in a state of compression, provided that the direction of the force applied does not fall within the angle if produced; but if the line of direction of the force applied fall within the angle of the triangle, then both legs are either in a state of tension or in a state of compression, according as the force applied is pulling or pressing; if one of the sides of the triangle be lengthened without the boundary, and a force be applied transversely to the part so lengthened, this force will bend the side of the figure which is in the straight line with the side to which the force is applied: therefore, suppose again a quadrangle, or quadrilateral, revolvable about the angles, and a bar be fixed to any two sides forming an angle, viz., a point in the bar to a point in one of the legs, and another point in the bar to a point in the other leg, and suppose the two points not to be in two of the angles, or one of the points to be in the side, at some distance from either end, the figure will be divided into two parts, one will always be a triangle; then, if it be supported at two of its angles, and a force be applied to the angle opposite, the angle which has the bar fixed to its legs, so that the direction of the force thus applied does not tend to the fixed point, which is the farther extremity of the one leg, where the force is applied to the angular point at the other extremity, all the sides of this figure will be bent, and the bar thus fixed will occasion transverse strains to the sides. But if the bar be fixed to two opposite angles, and if the frame be held immoveable at one of the angular points where the bar is fixed, and also at one of the other angles at the extremity

of one of the legs of the said angle, and a force in any direction in the plane of the figure be applied to the angle where the frame is unsupported, and where the bar is not fixed, the frame will be by this means rendered immoveable, and the force by this disposition will not occasion any transverse strain on the sides of the frame. Suppose the frame to be pentagonal, and a bar fixed in like manner to two angles, at the ends of two adjoining sides, these two adjoining sides and the bar will form a triangular compartment in the figure; if the frame be suspended by two of the angles of the triangle, the three remaining sides will be moveable at the extremities of the bar, and at the remaining angles; but if another bar be fixed to any one of the three angles of the triangle at one end, to one of the angles of the other three sides, to form another triangle, three of the sides of the pentagonal frame will be made immoveable, and the two remaining sides will be so likewise. In like manner, in whatever number of sides the frame consists, by first forming a triangle of two of the sides, and fixing a second bar from any angle of the triangle to one of the other angles of the figure, at the remote ends of two adjoining sides of this frame, will form another immoveable side, and give another immoveable point at the next angle of the frame; if, from this fixed point, or any of the other three points, which are the angles of the triangle, the end of a third bar be fixed, and the other end of the bar to one of the remaining angles of the frame, so as to form a triangle with the second bar and one of the adjoining moveable sides of the frame, or a triangle with one of the fixed sides of the frame and the adjoining moveable side; and by proceeding in this manner successively, until all the sides are fixed, the frame will be made immoveable; so that if any two angles of this frame be supported, and a force or forces be applied at one or each of the angles in the plane of the figure, the whole figure will be immoveable.

Frames of a triangular form, which have to resist only a single force, or support one weight, are most simply and best constructed of three sides; the frame being suspended from two angles, and the force or weight from the other. A triangular frame, supporting only one weight, has no occasion for any subdivision to compart the internal space, provided the compressed timber or timbers were inflexible, so as to support their own weight without bending, and the tensile timbers incapable of extension. Though a frame should have to support several weights, the external figure may be of any form whatever, provided that the points from which the weights are hung, and the two points from which the frame is suspended, be all immoveably supported by comparting the figure with timber divisions, and thereby forming a succession of adjoining triangles, of which each two contiguous have a common side; that is, when two of the angles of each of the adjacent triangles are coincident. It may be proper to observe here, that though it may not be at all times eligible to divide a frame, so that all the compartments will be triangles, yet the succession must not by any means be discontinued by the intervention of quadrilateral or polygonal figures, for these compartments may adjoin without injury to the truss. The triangle is the most simple of all rectilinear figures; it is also easier constructed, and better adapted to the discharge of rain or moisture in a roof, than any other figure; but, in its adoption to large buildings, as several weights must be supported, and as there is only one point from which this weight can be suspended, it becomes necessary to take other equidistant points in the sides, in order to support the covering equally: these points may be made stationary, by the former means of dividing the interior space into a succession of triangular compartments. But if the two upper sides of the frame be of equal lengths, and equally inclined to the horizon, the opposite points may be made to counteract each other without a concatenation of triangles, by introducing timbers from point to point, parallel to the horizon; in this the compartments will all be trapezoids, except the upper one, which will be a triangle. These beams may be supported by vertical bolts passing transversely through them from the points where the weights are supported, and the bolts may be nutted below the beams. This mode of securing the points of support depends entirely upon the doctrine of equilibrium, and thus a very little difference from the equality of forces might easily occasion a change of figure, to which the other method by a series of triangles is not liable. The securing of the points of support by beams is not confined to triangular frames, but may be applied to roofs having two or several rafters upon each side, so that their lengths and inclinations are equal, and their junctions on the same level. The beauty of every truss is to dispose the timbers in positions as direct to each other as possible: oblique directions require timbers of large scantlings, and exert prodigious thrusts on the abutments, so as to compress the joggle-pieces, and render the truss in danger of sagging. Trusses are variously constructed, according to the width of the building, and contour of the roof, and the circumstances of walling below.

The general principle of construction is a series of triangles, of which every two are connected by a common side.

Let A B C D E F G (see Plate I., Centering, *Figure* 1,) be the curve of the arch which requires a centre. Let the points A B C, &c., be connected, so as to form the equilateral polygon A B C D E F G, and join A C, C E, and E G; the timbers thus disposed will form three triangles, which may be looked upon as so many solids revolvable about the angular points, A, C, E, G; suppose now these to be in equilibrium, the smallest force on either side would throw it down; and therefore, without other connecting timbers, it would be unfit for the purpose of a centre.

Let A B C D E F G (Plate I., Centering, *Figure* 2,) be the curve of an arch which requires a centre. First, from the equilateral polygon, A B C D E F G, with the timbers, A B, C D, G D, &c., and fix the timbers A C, C E, E G, as before, which will form three triangles, moveable round A C E G; let the timbers B D and D F be fastened, and thus the whole will be immutable, so that if supported at the points A and G, and a force be applied at any other of the angles, B, C, D, or F, the timbers will be all in a state of tension, or in a state of compression, and the whole may be looked upon as a solid body. For since the sides and angular points of a triangle are fixed, when the triangle is supported at two of the angles, and a force applied to the other, let us suppose the triangle, A B C, to be supported at the points A and B, and the point C, and the other two sides, B C, C A, will be fixed; and because B C D is a triangle, and the points B and C are fixed, the point D, and consequently the sides C D and D B, are fixed. In like manner, since C D E is a triangle, and the points C and D fixed, the point E will also be fixed, and also the sides D E and E C. The same may be shown in like manner for the points F and G. Suppose, then, two equal and opposite forces applied at the points A and G, in the plane of the figure, the figure can neither be extended out nor compressed together. The pieces A H, H B, and G I, I F, are of no other use than to make the centre stand firmly on its base. This disposition of the timbers will cause them to occupy the least possible space.

If the timbers are fixed at the points *k*, *l*, *m*, *n*, *o*, *p*, the same immutability of figure may be demonstrated; for suppose the points A and H to be fixed, the point *k* will also

be fixed; the points A and *k* being fixed, the point B, of the triangle A *k* B, will likewise be fixed. Again, the points B and *k* being fixed, the point *l* will also be fixed: in the same manner, all the remaining points, C, *m*, D, *n*, *o*, F, *p*, G, L, may be proved to be stationary in respect of the points A, H; and the whole figure being kept in equilibrio by any three forces, acting in the plane of the figure at any three angles, the action of the forces will only tend to compress or extend the timbers in the direction of their length.

In the construction of this truss, the triangular parts may be constructed all in the same plane, and the pieces, B D and D F, may be halved upon the pieces C A and E G; but the utmost care must be taken to secure the several pieces concurring at each of the angles, by bolting, or iron straps, as no dependence can be put in any such joint without iron; but perhaps the best method of any is to halve the thicknesses of the pieces A C, C E, E G, at the points C and E, and also the pieces A B, B C, C D, D E, E F, F G, at the points B, D, F: then bolting the ends, A and C, of the pieces B A, B C, the end C and E, of the pieces D C and D E, and the ends E and G of the pieces F E and F G, and then fixing double braces, B D, D F; that is, fixing B D upon one side of the truss, and another upon the other side of the truss, opposite to it; also fixing D F upon one side, and another opposite to it.

Figure 6, of the same plate, represents the manner of constructing a centre according to the principles of Perronet, the celebrated French engineer; but the disposition of the timbers, forming only a series of quadrilaterals, gives nothing but immutability of figure; and can, therefore, only derive its stiffness from the resistance of the joints.

Having thus given a general account of the principles of centering, as connected with the article Carpentry, we must refer our readers to the article STONE BRIDGE for its application, and other practical remarks in the construction.

MECHANICAL POWERS, such machines as are used for raising greater weights, or overcoming greater resistances, than could be effected by the natural strength without them; the power or strength being applied to one part of the machine, and another part of the machine applied to the weight or resistance. In treating of each of which, two principal problems ought to be resolved.

The first is, to determine the proportion which the power and weight ought to have to each other, that they may just sustain one another, or be in equilibrio.

The second is, to determine what ought to be the proportion of the power and weight to each other in a given machine, that it may produce the greatest effect possible, in a given time.

As to the first problem, this general rule holds in all powers: suppose the engine to move, and reduce the velocities of the power and weight to the respective directions in which they act; find the proportions of these velocities; then, if the power be to the weight as the velocity of the weight is to the velocity of the power,—or, which amounts to the same thing, if the power multiplied by its velocity, gives the same product as the weight multiplied by its velocity,—this is the case wherein the power and weight sustain each other, and are in equilibrio; so that in this case the one would not prevail over the other, if the engine were at rest; and if in motion, it would continue to proceed uniformly, were it not for the friction of its parts, and other resistances.

The second general problem in mechanics is, to determine the proportion which the power and weight ought to bear to each other, that when the power prevails, and the machine is in motion, the greatest effect possible may be produced by it in a given time. It is manifest, that this is an inquiry of the greatest importance, though few have treated of it. When the power is only a little greater than that which is sufficient to sustain the weight, the motion is too slow; and though a greater weight is raised in this case, it is not sufficient to compensate the loss of time. When the weight is much less than that which the power is able to sustain, it is raised in less time; and this may happen not to be sufficient to compensate the loss arising from the smallness of the load. It ought, therefore, to be determined when the product of the weight, multiplied by its velocity, is the greatest possible; for this product measures the effect of the engine in a given time, which is always the greater in proportion as the weight which is raised is greater, and as the velocity with which it is raised is greater.

The simple machines by which power is gained are six in number, viz., the *lever*, the *wheel and axle*, or *axis in peritrochio*, the *pulley* (or rather system of pulleys), the *inclined plane*, the *wedge*, and the *screw*. Of these, all sorts of mechanical engines consist; and in treating of them, so as to settle their theory, we must consider them as mechanically exact, and moving without friction. For the properties and applications of the mechanical powers, see LEVER, PLANE (INCLINED), PULLEY, WEDGE, and WHEEL.

MEDALLION (from the French), in architecture, a circular tablet, on which are embossed figures, bustos, or other ornaments.

MEDIÆVAL ARCHITECTURE, comprises all those styles which were prevalent during what are commonly, though unfairly, styled the dark ages, viz., from the fall of the Roman empire to the revival of classic art. It includes those styles which may be peculiarly termed Christian, amongst which may be enumerated the Romanesque, the Byzantine, and Lombardic, and more especially the Gothic style. These are treated of under their distinctive titles.

MEDIANÆ, in Vitruvius, the columns in the middle of the portico, where the intercolumniation is enlarged.

MEMBER (from the French) any part of an edifice; or any moulding in a collection.

MENSURATION (from the Latin *mensura*, measurement) that branch of mathematics which is employed in ascertaining the extension, solidities, and capacities of bodies; and in consequence of its very extensive application to the various purposes of life, it may be considered as one of the most useful and important of all the mathematical sciences: in fact, mensuration, or geometry, which were anciently nearly synonymous terms, seem to have been the root whence all the other exact sciences, with the exception of arithmetic, have derived their origin.

As soon as men began to form themselves into society, and direct their attention towards the cultivation of the earth, it became as necessary to have some means of distinguishing one person's allotment from another, both as to position and quantity, as it did to enumerate the number of their flocks and herds; and hence, in all probability, the former gave rise to the science of mensuration, as the latter did to that of arithmetic; and though we may easily imagine that each of them remained for ages in a rude uncultivated state, yet it is from this period that we must date their commencement; and therefore, to state the precise time when they were discovered, or by whom they were first introduced, would be to trace out the origin of society itself: on this head, therefore, we shall barely observe, that in all probability they first arose from the humblest efforts of unassisted genius, called forth by the great mother of invention, necessity; and that they have since grown up by slow and imperceptible degrees, till they have at length acquired the dignity of the most perfect sciences; as the acorn which is first accidentally sown in a field, is in due course of time converted into the majestic oak

But notwithstanding we cannot attribute the invention of the science of mensuration to any particular person or nation, yet we may discover it in an infant state, rising, as it were, into a scientific form, amongst the ancient Egyptians; and hence the honour of the discovery has frequently been given to this people, and to the circumstance of the overflowing of the Nile, which takes place about the middle of June, and ends in September. It is, however, to the Greeks that we must consider ourselves indebted for having first embodied the leading principles of this art into a regular system. Euclid's *Elements of Geometry* were probably first wholly directed to this subject; and many of those beautiful and elegant geometrical properties, which are so much and so justly admired, it is not unlikely, arose out of simple investigations directed solely to the theory and practical application of mensuration. These collateral properties, when once discovered, soon gave rise to others of a similar kind; and thus geometry, which was first instituted for a particular and limited purpose, became itself an independent and important science, which has perhaps done more towards harmonizing and expanding the human faculties, than all the other sciences united.

But notwithstanding the perfection which Euclid attained in geometry, the theory of mensuration was not in his time advanced beyond what related to right-lined figures; and this, so far as regards surfaces, might all be reduced to that of measuring a triangle; for as all right-lined figures may be reduced to a number of trilaterals, it was only necessary to know how to measure these, in order to find the surface of any other figure whatever bounded only by right lines. The mensuration of solid bodies, however, was of a more varied and complex nature, and gave this celebrated geometrician a greater scope for the exercise of his superior talents, and, still confining himself to bodies bounded by the right-lined plane superficies, he was able to perform all that can be done even at this day. With regard to curvilinear figures, he attempted only the circle and the sphere, and if he did not succeed in those, he failed only where there was no possibility of success; but the ratio that such surfaces and solids have to each other he accurately determined.

After Euclid, Archimedes took up the theory of mensuration, and carried it to a much greater extent. He first found the area of a curvilinear space, unless, indeed, we except the lunules of Hippocrates, which required no other aid than that of the geometrical elements. Archimedes found the area of the parabola to be two-thirds of its circumscribing rectangle, which, with the exception above stated, was the first instance of the quadrature of a curvilinear space. The conic sections were at this time but lately introduced into geometry, and they did not fail to attract the particular attention of this celebrated mathematician, who discovered many of their very curious properties and analogies. He likewise determined the ratio of spheres, spheroids, and conoids, to their circumscribing cylinders, and has left us his attempt at the quadrature of the circle. He demonstrated that the area of a circle is equal to the area of a right-angled triangle, of which one of its sides about the right angle is equal to the radius, and the other equal to the circumference, and thus reduced the quadrature of the circle to that of determining the ratio of the circumference to the diameter, a problem which has engaged the particular attention of the most celebrated mathematicians of all ages, but which remains at present, and in all probability ever will remain, the desideratum of geometricians, and, at the same time, a convincing and humiliating proof of the limited powers of the human mind.

But, notwithstanding Archimedes failed in establishing the real quadrature of the circle, it is to him we are indebted for the first approximation towards it. He found the ratio between the diameter of a circle, and the periphery of a circumscribed polygon of 96 sides, to be less than 7 to 22, or less than 1 to $3\frac{10}{70}$; but the ratio between the diameter, and periphery of an inscribed polygon of the same number of sides, he found to be greater than 1 to $3\frac{10}{71}$; whence *à fortiori*, the diameter of a circle is to its circumference in a less ratio than 1 to $3\frac{1}{7}$, or less than 7 to 22. Having thus established this approximate ratio between the circumference and diameter, that of the area of the circle to its circumscribed square, is found to be nearly as 11 to 14. Archimedes, however, makes the latter the leading proposition. These, it is true, are but rude approximations, compared with those that have been since discovered; but, considering the state of science at this period, particularly of arithmetic, we cannot but admire the genius and perseverance of the man, who, notwithstanding the difficulties that were opposed to him, succeeded in deducing this result, which may be considered as having led the way to the other more accurate approximations which followed, most of which, till the invention of fluxions, were obtained upon similar principles to those employed by this eminent geometrician. Archimedes also determined the relation between the circle and ellipsis, as well as that of their similar parts; besides which figures, he has left us a treatise on the spiral, a description of which will be given under that article. See SPIRAL.

Some advances were successively made in geometry and mensuration, though but little novelty was introduced into the mode of investigation till the time of Cavalerius. Till his time, the regular figures circumscribed about the circle, as well as those inscribed, were always considered as being limited, both as to the number of their sides, and the length of each. He first introduced the idea of a circle being a polygon of an infinite number of sides, each of which was, of course, indefinitely small; solids were supposed to be made up of an indefinite number of sections indefinitely thin, &c. This was called *the doctrine of indivisibles*, which was very general in its application to a variety of difficult problems, and by means of it many new and interesting properties were discovered: but it unfortunately wanted that distinguishing characteristic which places geometry so pre-eminent amongst the other exact sciences. In pure elementary geometry, we proceed from step to step, with such order and logical precision, that not the slightest doubt can rest upon the mind with regard to any result deduced from those principles; but in the new method of considering the subject, the greatest possible care was necessary in order to avoid error, and frequently this was not sufficient to guard against erroneous conclusions. But the facility and generality which it possessed, when compared with any other method then discovered, led many eminent mathematicians to adopt its principles, and of these, Huygens, Dr. Wallis, and James Gregory, were the most conspicuous, being all very fortunate in their application of the theory of indivisibles. Huygens, in particular, must always be admired for his solid, accurate, and masterly performances in this branch of geometry. The theory of indivisibles was, however, disapproved of by many mathematicians, and particularly by Newton, who, amongst his numerous and brilliant discoveries, has given us that of the method of fluxions, the excellency and generality of which immediately superseded that of indivisibles, and revived some hopes of squaring the circle, and accordingly its quadrature was again attempted with the greatest eagerness. The quadrature of a space, and the rectification of a curve, was now reduced to that of finding the fluent of a given fluxion; but still the problem was found to be incapable of a general

solution in finite terms. The fluxion of every fluent was found to be always assignable, but the converse proposition, viz., of finding the fluent of a given fluxion, could only be effected in particular cases, and amongst these exceptions, to the great disappointment and regret of geometricians, was included the case of the circle, with regard to all the forms of fluxions under which it could be obtained.

At length, all hopes of accurately squaring the circle and some other curves being abandoned, mathematicians began to apply themselves to finding the most convenient series for approximating towards their true length and quadrature; and the theory of mensuration now began to make rapid progress towards perfection. Many of the rules, however, were given in the transactions of learned societies, or in separate and detached works, till at length Dr. Hutton formed them into a complete treatise, intitled, *A Treatise on Mensuration*, in which the several rules are all demonstrated, and some new ones introduced. Mr. Bonnycastle also published a very neat work on this subject, intitled *An Introduction to Mensuration*. Several books on the subject have been published since the above, which, notwithstanding, still maintain their high reputation.

Particular rules for measuring the various kinds of geometrical figures and solids will be found under their respective heads; but as a collection of examples of the mensuration of distances capable of application to the purposes of enginery and architecture is a desideratum in science, the following, likely to occur in general practice, are here inserted.

Mensuration of Lines.

Problem I.—*Any two sides of a right-angled triangle being given, to find the third.*

Case I.—When the two legs are given, to find the hypothenuse.

Rule.—Add the squares of the two legs together, and the square root of the sum will give the hypothenuse.

Example 1.—In the right-angled triangle, A B C, are given the base, A B, equal to 195 feet, and the perpendicular, B C, = 28 feet: what is the length of the hypothenuse, A C?

195	28
195	28
975	224
1755	56
195	784

$(A\,B)^2 = 38025$
$(B\,C)^2 = 784$

3,88,09 (197 = A C
1

29) 288
261

387) 2709
2709

Example 2.—If the span, A B, of a roof, be 24 feet, and the height, D C, 5 feet, what should be the length of the rafters, A C and C B.

This is resolved into two equal and similar right-angled triangles, as follows:—

$24 \div 2 = 12$, the half base.

$(12^2 + 5^2)^{\frac{1}{2}} = 13$, the answer.

Case II.—When the hypothenuse and one of the legs are given, to find the other leg.

Rule.—From the square of the hypothenuse take that of the given leg; and the square root of the difference will be the leg required.

Example 1.—In the right-angled triangle, A B C, are given the hypothenuse B C, 601, the perpendicular A C, 240; required the base.

$(601^2 - 240^2)^{\frac{1}{2}} = 551$, the answer.

Example 2.—In a roof, whose span, A B, is 45 feet 6 inches, and the rafters, A C or B C, 25 feet 5 inches; required the height, D C, of the roof.

45 .. 6	25 .. 5
12	12
2) 546	Rafter, 305 inches.

Base of each triangle, 273 inches.

Then will $(305^2 - 273^2)^{\frac{1}{2}}$ = Inches. Feet. Inches. 136 = 11 .. 4 the answer.

Example 3.—In a roof, whose rafters are each 26 feet, and the perpendicular height 10 feet, what is the span or distance between the feet of the rafters?

$(26^2 - 10^2)^{\frac{1}{2}} = 24$ feet, half the span.

Consequently, 48 feet is the distance between the feet of the rafters.

Examples for Practice.

1. Given the hypothenuse, 1625 yards, and the perpendicular, 400; required the base.—*Answer*, 1575 yards.

2. Wanted to prop a building with raking-shores at the height of 25 feet from the ground, having several pieces of wood of equal length which might be used for the purpose, each 30 feet long; how far must the bottom of the shores be placed from the base of the building?—*Answer*, 16,583.

The following rule for the construction of right-angled triangles, the sides of which shall be commensurable with each other, may be found useful in the practice of constructing roofs.

Rule.—Take any two square numbers at pleasure; then their sum, their difference, and the double product of their roots, will give the sides of a right-angled triangle, which shall be commensurable with each other.

Example 1.—Let the two square numbers 1 and 4 be taken: the roots of which are 1 and 2.

Then $4 + 1 = 5$, the hypothenuse.
$4 - 1 = 3$, one of the legs,
and $2 \times 2 \times 1 = 4$, the other leg, equal to double the product of the roots; consequently, 3, 4, 5, are the numbers required, and are the least numbers by which a right-angled triangle can be constructed.

Example 2.—Let the two square numbers be 144 and 25.

Then $144 + 25 = 169$, the hypothenuse.
$144 - 25 = 119$, one of the legs.
$2 \times 12 \times 5 = 120$, the other leg.

In this manner an infinite variety of ratios may be found for the sides of right-angled triangles.

The above rule may be found in some books of arithmetic; but having obtained the three sides, suppose 169, 119, 120, the following progressive table of ratios may be constructed, by adding 10 continually to the fourth column, and the opposite number of the vertical arithmetical progressive column on the left hand to each horizontal number in the second and third columns, which will generate those immediately below.

Example.—To generate the numbers 194, 144, 130: Add 25 to 169, and the sum will be 194, the hypothenuse of the triangle. In like manner, $25 + 119 = 144$, one of the legs;

and by adding 10 to 120, we have 130, the other leg. And thus, in every instance, each horizontal number will be generated by adding the number in the vertical left-hand column to each of the two adjacent numbers in the second and third columns of the same horizontal line, and by adding 10 to the number expressed in the fourth.

Generating numbers.	Sides of a right-angled triangle, expressed by any three of the horizontal numbers.			Ratio of the two legs.
25	169	119	120	$1\frac{1}{119}$
27	194	144	130	$1\frac{7}{65}$
29	221	171	140	$1\frac{31}{140}$
31	250	200	150	$1\frac{1}{3}$
33	281	231	160	$1\frac{71}{160}$
35	314	264	170	$1\frac{47}{85}$
37	349	299	180	$1\frac{119}{180}$
39	386	336	190	$1\frac{72}{95}$
41	425	375	200	$1\frac{7}{8}$
43	466	416	210	$1\frac{103}{105}$
45	509	459	220	$2\frac{19}{220}$
47	554	504	230	$2\frac{22}{115}$
49	601	551	240	$2\frac{71}{240}$
51	650	600	250	$2\frac{2}{5}$
53	701	651	260	$2\frac{131}{260}$
55	754	704	270	$2\frac{164}{270}$
57	809	759	280	$2\frac{109}{280}$
59	866	816	290	$2\frac{118}{145}$
61	925	875	300	$2\frac{11}{12}$
63	986	936	310	$3\frac{3}{155}$
65	1049	999	320	$3\frac{39}{320}$
67	1114	1064	330	$3\frac{32}{165}$
69	1181	1131	340	$3\frac{111}{340}$
71	1250	1200	350	$3\frac{5}{7}$
73	1321	1271	360	$3\frac{191}{360}$
75	1394	1344	370	$3\frac{117}{185}$
77	1469	1419	380	$3\frac{279}{380}$
79	1546	1496	390	$3\frac{326}{390}$
81	1625	1575	400	$3\frac{13}{16}$
83	1706	1656	410	$4\frac{8}{205}$

Problem II.—*To find the length of a cylindrical helix.*

Rule.—Multiply the circumference of the base by the number of revolutions; to the square of the product add the square of the height of the spiral, or the square of the distance of the axis from the beginning to the end; and the square root of the sum will be the length of the spiral.

The form of the cylindric helix is a right-angled triangle, the base of which is the number of revolutions, and the height that of the spiral: *i. e.*, if the whole were unwound and stretched upon a plane, the development would be a right-angled triangle.

Example 1.—Required the length of a screw twisting round a cylinder 22 inches in circumference, $3\frac{1}{2}$ times, and extending along the axis 16 inches.

22	16
$3\frac{1}{2}$	16
66	96
11	16
77 base of the developn	256
77	
539	
539	
5929 square of the base.	

[*Continued*—

5929 square of the base.
256 square of the altitude.

6185 (78.64 inches, the answer.
49

148) 1285
1184

1566) 10100
9396

15724) 70400
62896

7504

Example 2.—Required the number of feet of hand-railing for a semicircular stair, consisting of 9 winders, each $6\frac{1}{2}$ inches high, the diameter of the well-hole being 18 inches.

Problem III.—*The chord and versed sine of an arc of a circle being given, to find the diameter.*

Rule 1.—Divide the sum of the squares of the sine and the versed sine by the versed sine itself, and the quotient is the diameter.

Example 1.—Given, the chord, A B = 48 feet, and the versed sine, D E = 18 feet; required the diameter.

$\frac{48}{2} = 24$, the sine, or half chord.

Then $\frac{24^2 + 18^2}{18} = 50$, the diameter required.

This arithmetical operation of finding the radius is much preferable to the geometrical construction, the calculation being so easy, and performed in a very small compass; whereas the other mode requires a floor, or flat surface, to describe it upon, which cannot at all times be obtained; recourse must therefore be had to a temporary floor of rough boarding, which requires an immense time in the preparation, and when done is not much to be depended upon.

Examples for Practice.

A room is to be constructed with a cylindric bow, the plan being the segment of a circle, whose chord is 18 feet, and the height of the segment 6 feet; what length of a rod will be necessary to describe the arc?

A bridge is to be constructed of a cylindric intrados, the section of which is to be the segment of a circle, to span 100 feet, and to rise 33 feet; what length of a line, or wire, will be necessary to describe the arc?

Rule 2.—As the versed sine is to the half chord, so is the half chord to a fourth proportional; add this fourth proportional to the versed sine, and the sum is the diameter: thus, take the dimensions in the preceding example; we have

$$18 : 24 :: 24 : \frac{24 \times 24}{18} = 32;$$

then $32 + 18 = 50$, the diameter.

Problem IV.—*In the segment of a circle are given the chord, and its distance from the centre; to find the radius of the circle.*

Rule.—Add the square of the half chord to the square of the distance; and the square root of the sum will be the radius of the circle.

Example 1.—Let the chord, A B, be 8 feet, and the distance of A B from the centre, C D, 3 feet; required the radius of the circle.

Here $\frac{8}{2} = 4$ the half chord.

Then $(4^2 + 3^2)^{\frac{1}{2}} = 5$, the answer.

Or thus, at full length.

4	3
4	3
16	9
9	
25 (5, the answer.	

Example 2.—In Stewart's *Ruins of Athens*, vol. II. pl. vi. ch. 1, are given, in a section of the columns of the portico of the temple of Minerva at Athens, the distance between the chords of two opposite equal and parallel flutes, 6 feet 1.8 inches, and the chord of each flute 11.688 inches; required the diameter of the column, which he has omitted.

6 1.8	2) 11.688
12	
2) 73.8 diameter reduced to inches.	5.844 half chord.
36.9	

Inches.

$(36.9^2 + 5.844^2)^{\frac{1}{2}} = 37.36$ the radius nearly.

PROBLEM V.—*The radius of a circle being given, and the chord of a segment of that circle: to find the versed sine of the lesser segment.*

RULE.—*Method* 1.—Subtract the square of the half chord from the square of the radius, and the square root of the difference will be the cosine; subtract the cosine from the radius, and their difference will be the versed sine of the lesser segment; that is, $v = r - (r^2 - y^2)^{\frac{1}{2}}$.

Example.—A weir is to be constructed across a river, in the arc of a circle of 250 feet radius; the span of the river, or chord, to be 200 feet; what is the versed sine of the lesser segment?

$250 - (250^2 - 100^2)^{\frac{1}{2}} = 20.87122$, the versed sine required.

N. B. If the versed sine of the greater segment is required, add the cosine to the radius, and the sum will be the versed sine.

Method 2.—When the chord is very small, and the diameter large.

As the diameter of the circle is to the half chord, so is the half chord to the versed sine, nearly.

Example 1.—Suppose a bridge is to be executed, 56 feet in diameter, the breadth or chord of each stone on the face and on the intrados of the arch being 12 inches; what is the versed sine, or height of the arc of a single stone?

56	
12	
672 : 6 : : 6	
6	
672) 36.000(.053 inches nearly.	
33 60	
2 400	
2 016	
384	

Example 2.—Supposing the diameter of the earth to be 7957 miles, how much does the curvature rise in a chord of 2 miles?

We have 7957 : 1 : : 1 : .000125 of a mile, which reduced gives 7.92 inches nearly for the rise of the arc.

This would also be the distance that the curvature of the earth would fall from the tangent in one mile.

N. B. The deflection of the arc from the level is as the square of the distance from the point of contact nearly. This proportion would give the same result as the method by which this example is wrought.

PROBLEM VI.—*Given the distance between the two parallel sides of a trapezoid, and the breadth of the lesser end; to find the breadth of the greater end, so that the sides may tend to a point at any given distance.*

Note.—The distance from the lesser end to the given point is here termed *the distance of the point of convergence.*

RULE.—As the given distance is to the sum of that distance, and the distance to the point of convergence; so is the breadth of the lesser end to that of the greater.

Example 1.—Given the distance, E F, between the parallel sides, A B and D C, of a trapezoid A B C D, equal to 3 feet; the breadth of the lesser end, D C, 2 feet; and the distance, E G, from the lesser end, D C, to the point, G, of the meeting of the inclined sides, A D and B C, 58 feet; required the breadth, A B, of the greater end.

$58 : 58 + 3 : : 2 : \frac{(58 + 3) \times 2}{58} = 2.103$, the breadth of the greater end.

Example 2.—A stone weir is to be constructed across a river, in the form of the segment of a circle, with the convex side of the arc towards the stream; the joints of the stones being all to tend to the centre: now the length of each stone in the direction of a radial is 4 feet, the radius 250 feet, and the breadth of the lesser end of the stone 1 foot; required the breadth of the upper end of the stones.

Foot. In. Sec.

Answer, 1.016 feet, or, 1 0 2

This problem is also useful in perspective, in the drawing of two lines towards a vanishing point.

Example 3.—A bridge is to be constructed of a cylindric intrados, the section of which is the segment of a circle of 28 feet radius, the length of the archstones are to be 2 feet, and their breadth in front of the arch and on the intrados 1 foot; required the breadth of the thick end of the stone.

28 : 28 + 2 : : 1 to the answer.

Or,

28 : 30 : : 1	
1	
28)30(1.0714 the breadth of the greater end, as required.	
28	
200	
196	
40	
28	
120	
112	
8	

Or, the answer may be reduced to the workman's rule for taking his dimensions, thus:

1.0714
12

.8568
8

6.8544
4

3.4176

This gives one foot and very nearly seven-eighths of an inch, the foot being divided into twelve equal parts, called *inches*, and each inch into eight equal parts; the workmen seldom regard anything less than the sixteenth part of an inch.

This example corresponds to Problem V. Method 2, which ascertains the versed sine of the arc of the stone of a bridge, weir, or the like, of a given radius and given chord: it likewise ascertains the taper that the stones should have in the direction of a radius. The mould of the section of the stones may therefore be found by calculation, and the arc described by Problem LII. of the article GEOMETRY, almost within the compass of the section itself, without having recourse to the long distance of a centre, which not only requires an inconvenient degree of space, but occasions great loss of time in the preparation.

PROBLEM VII.—*To find any point in the arc of the segment of a circle at the extremity of an ordinate; the radius of the circle, the chord of the arc, and the distance of the ordinate from the middle of the chord, being given.*

RULE.—Find the versed sine by Problem V. subtract it from the radius, and the remainder will be the cosine; subtract this cosine from the square root of the difference of the squares of the radius and of the distance from the middle of the chord to the ordinate, and the difference will give the length of the ordinate.

Example.—Suppose the radius, A D, of the segment, G E H, to be 250 feet, the chord, G H, 200 feet, and the distance from the middle B, of the chord to the ordinate, C D, 50 feet; required the ordinate, C D.

The versed sine I E, will be found to be 20.871, by Problem V., consequently, $250 - 20.871 = 229.129$ the cosine; therefore $(250^2 - 50^2)^{\frac{1}{2}} - 229.129 = 15.820$ feet, the answer.

In the following examples, the radius and chord are the same as in the last; but the variation is in the distance of the ordinate from the middle of the chord.

EXAMPLES FOR PRACTICE, TO BE ANSWERED.

Let the distance from the middle of the chord to the ordinate be 10; required the ordinate.—*Answer.*

Let the distance from the middle of the chord to the ordinate be 20; required the ordinate.—*Answer.*

Let the distance from the middle of the chord to the ordinate be 30; required the ordinate.—*Answer.*

Another rule, without finding the versed sine, is as follows:

First.—Find the cosine of G E, the half arc, thus: from $(250)^2$ viz. the square of the radius, subtract $(100)^2$ viz. the square of the sine, or half chord, 200; and the square root, 229.129, of the remainder gives A B, the cosine of the arc G E.

Secondly.—Find the cosine of the arc D E in the same manner, thus; from $(250)^2$ viz. the square of the radius, subtract $(50)^2$, viz. the square of the sine, or half chord, of 100, that is, the distance from B to C; and the square root, 244.949, of the remainder gives A I the cosine of the arc D E.

Thirdly.—Subtract the cosine, A B = 229.129, of the greater arc G E, from the cosine A I = 244.949 of the lesser arc, D E; and the remainder, B I = 15.82, is equal to the ordinate C D.

PROBLEM VIII.—*Given the chord of a very large segment of a circle, and the radius of the circle; to find any number of points in the arc, and thence to describe it.*

RULE.—Divide the chord into any number of convenient equal parts each way from the middle, and erect ordinates upon the points of division; calculate the length of each ordinate by the last problem; find the versed sine to a chord not less than the distance between the two most remote adjacent points in the ends of the arc; describe an arc to this chord and versed sine by Problem LII. of the article GEOMETRY; then procure a board equal to the length of the chord, and curve its edge to the arc; with the curved edge draw an arc between every two points of the extended arc, and the entire arc will be formed.

N. B. There are several methods of describing segments of circles, as shown under the article GEOMETRY; but none so eligible, upon a large scale, where accuracy is required, as the above. It will be found convenient to erect the ordinates ten feet apart on each side of the middle of the chord, though the last distance at each end, between the extreme ordinate and the extreme of the curve, should be less than the intermediate 10 feet distances. Boards in general do not exceed 10 or 12 feet; but a twelve-foot board will be sufficient for ten-foot distances on the chord, in most cases, even when the versed sine rises high in proportion to the chord.

Example.—An engineer intending to construct a stone weir over a river, in the arc, A L M, of a circle; the chord, A M, of which being 200 feet, and the radius 250 feet; required the length of the ordinates at 10 feet distance from each other, and the versed sine to a chord of 12 feet, for completing the arc.

N L, the versed sine	20.871	Problem V.
O K, the first ordinate . . .	20.671	Problem VII.
P I, the second ditto	20.07	ditto.
Q H, the third ditto	19.065	ditto.
R G, the fourth ditto	17.651	ditto.
S F, the fifth ditto	15.82	ditto.
T E, the sixth ditto	13.565	ditto.
U D, the seventh ditto . . .	10.872	ditto.
V C, the eighth ditto	7.726	ditto.
W B, the ninth ditto	4.11	ditto.

These ordinates are respectively calculated at 10, 20, 30, 40, 50, 60, 70, 80, 90 feet distance from the middle of the chord to each ordinate.

It now remains to calculate the versed sine corresponding to a chord of 12 feet of the same arc as that of the weir: This will be found by Problem V. to be .072 of a foot, or very nearly seven-eighths of an inch, being, as workmen say, bare measure. Curve the edge of a twelve-foot board to a versed sine of seven-eighths of an inch; then lay the curved edge, with the concave side towards the chord, successively between every two points, A, B; B, C; C, D, &c., drawing each part until the whole arc is completed to the chord A M.

N. B.—A boarding is generally fixed to a timber grating or framing, supported by piles, for the foundation of the stone-work.

PROBLEM IV.—*In a parabola having two abscissas and an ordinate to one of them, to find the ordinate of the other.*

RULE.—As the abscissa of the given ordinate is to the abscissa of the required ordinate, so is the square of the ordinate of the former abscissa to the square of the ordinate

of the latter. Then the root of the fourth term so found will be the ordinate required.

Example.—In the parabola, A B C A, are given the base, or double ordinate, A C, 18 feet, the height, or abscissa, B D, 16 feet, and the abscissa, B E, 8 feet; required the ordinate, E F.

$\frac{18}{2} = 9$, the ordinate.

and $9^2 = 81$.

$$16 : 8 :: 81 : \frac{81 \times 8}{16} = 40.5 \text{ the square of E F.}$$

Therefore, $40.5^{\frac{1}{2}} = 6.364 =$ E F, the ordinate required.

In this manner any number of ordinates, and consequently of points, may be found in the curve, so as to construct the figure. This method is the most appropriate for use in the formation of the curve, when the abscissa is greater than the ordinate, or equal to it.

Problem V.—*To find any point in the curve of a parabola by means of an abscissal parallel, or transverse ordinate; the height, or abscissa, the ordinate, and the distance of the transverse ordinate from the abscissa, being given.*

Note.—A transverse ordinate, or abscissal parallel, is a right line terminated by the curve and by the base parallel to the abscissa, commonly called a *diameter*, in this particular curve.

Rule.—Multiply the difference of the squares of the ordinate and of the distance of the abscissal parallel, or transverse ordinate, from the abscissa, by the height; divide the product by the square of the ordinate, and the quotient will give the height of the transverse ordinate.

Or, thus: Take any two numbers, in the proportion of the ordinate, or half base, and the distance between the abscissa and transverse ordinate; call these numbers respectively A and B: multiply the difference of the squares of A and B by the height; divide the product by the square of A; and the quotient will give the transverse ordinate.

Example.—In the parabola, A B C, are given the abscissa, B D, 8 feet, the ordinate, A D, 40 feet, and the distance, D E, 16 feet; to find the abscissal parallel, or the transverse ordinate, E F.

$$\frac{(40^2 - 16^2) \times 8}{40^2} = 6.72 \text{ feet, the answer.}$$

Or, because 5 and 2 are in the same proportion as 40 and 16, we have $\frac{(5^2 - 2^2) \times 8}{5^2} = 6.72$ feet, as before.

This method, as it avoids the square root, will not only be easier than the last, of finding a point in the curve of the parabola, but will be much more accurate when the abscissa is less than the ordinate.

Problem XI.—*Given the abscissa and ordinate of a parabola, to find any number of equidistant diameters, or abscissal parallels, and consequently points, in the curve, at the extremities.*

Take the simple arithmetical progression of the numerical scale 1, 2, 3, 4, 5, &c. till the last contain as many units as the number of equal parts intended to be contained in the ordinate. Then if the last number represent the ordinate, the preceding numbers, 1, 2, 3, &c., will represent the respective distances that each transverse ordinate is from the abscissa. Proceed with these numbers as distances, and calculate as in the last Problem, and the several results will give the ordinates.

Or thus: If a double ordinate be given, and the number of transverse ordinates be even, or the equal parts of the double ordinate odd, take the odd numbers of the arithmetical progression 1, 3, 5, 7, &c., and proceed as above: and having found the transverse ordinates, let the real base, or double ordinate, be divided into the equal parts required, and perpendiculars erected at the points of division, and made respectively equal to the results on each side of the abscissa, will give the transverse ordinates, and consequently as many points in the curve.

This method applies to the construction of a parabola of very great extent, as the extrados of a bridge, not for one arch only, but for the upper line of a series of arches. The parabolic curve is well adapted to bridges, as it gets quicker towards the middle, and therefore the contrast with the land is not so violent as the circular arc, which has the same curvature at the ends as in the middle. The use of transverse ordinates in constructing the curve, is not only more expeditious in calculation, but more accurate in ascertaining the curve at the vertex.

Synopsis of the Principal Rules of Mensuration.

Theorem I. Rule 1.—The circumference, c, of a circle being given, to find the diameter, d.

$$d = \frac{c}{3.1416}.$$

Theorem II. Rule 2.

$$d = \frac{7c}{22}.$$

The Rectification or Development of Curves.

Theorem I. Rule 1.—To rectify or develop the circumference of a circle.

$$c = 3.1416\, d.$$

Theorem II. Rule 2.

$$c = \frac{22\, d}{7}.$$

Theorem III. Rule 1.—To rectify the arc of a circle, the radius, r, and the sine, s, of half the arc, being given.

Let z be the length of the arc required, in all the following cases; then

$$z = 2\, s + \frac{1.1\, q}{2.3}\text{A} + \frac{3.3\, q}{4.5}\text{B} + \frac{5.5\, q}{6.7}\text{C}, \text{ \&c. where } q = \frac{s^2}{r^2},$$

and A, B, C, the preceding terms.

Theorem IV. Rule 2.—Let h equal the chord of the half arc, and c equal the chord of the whole arc.

$$z = \frac{8\, h - c}{3}, \text{ by Huygens.}$$

Theorem V. Rule 3.—The diameter, d, the versed sine, v, and the chord, c, being given:

$$z = c + \frac{4\, v\, c}{6\, d - 5\, v} = c \times \frac{6\, d - v}{6\, d - 5\, v} = 2 \times (dv - v^2)^{\frac{1}{2}} \times \frac{6\, d - v}{6\, d - 5\, d}.$$

Theorem VI. Rule 4.—The chord, c, and the versed sine, v, being given:

$$z = c + \frac{8\, v^2\, c}{3\, c^2 + 2\, v^2}, \text{ or } c\, \frac{3\, c^2 + 10\, v^2}{3\, c^2 + 2\, v^2}.$$

THEOREM VII. RULE 5.—The sine, s, and versed sine, v, of half the arc being given:

$$z = 2s + \frac{8v^2 s}{6s^2 + v^2}, \text{ or } 2s\,\frac{6s^2 + 5v^2}{6s^2 + v^2}.$$

THEOREM VIII. RULE 6.—The diameter, d, the sine, s, and versed sine, v, of half the arc, being given:

$$z = \frac{22ds}{11d - 8v}, \text{ or } 22s\,\frac{s^2 + v^2}{11s^2 + 3v^2}.$$

THEOREM IX. RULE 7.—The radius, r, the chord, c, and versed sine, v, being given:

$$z = c + \frac{cv}{3r} + \frac{v^3}{cr}.$$

THEOREM X. RULE 1.—To rectify the curve of an ellipsis, the major axis, t, and the minor axis, c, being given:

$z = \text{A} - \frac{d}{2.2}\text{A} - \frac{3d}{4.4}\text{B} - \frac{3.5d}{6.6}\text{C} - \frac{5.7d}{8.8}$, &c., where $d = \frac{t^2 - c^2}{t^2}$; and A, B, C, &c., are the preceding terms.

THEOREM XI. RULE 2.

$$z = \frac{23t + 21c}{14}.$$

AREAS OF PLANE SURFACES.

In the following theorems, let A be the proposed area.

THEOREM I.—To find the area of a parallelogram; the length, l, and the breadth, b, at right angles to the length, being given:

$$= lb.$$

THEOREM II. RULE 1.—To find the area of a triangle; the base, b, and the perpendicular height, h, from the opposite angle, being given:

$$\text{A} = \frac{bh}{2}.$$

THEOREM III. RULE 2.—The three sides, a, b, c, being given, let s be the half sum of the three sides, then

$$\text{A} = (s \times \overline{s - a} \times \overline{s - b} \times \overline{s - c})^{\frac{1}{2}}.$$

THEOREM IV. RULE 3.—Given, b, the base, and s, the half sum of the two opposite sides:

$$\text{A} = \tfrac{1}{4}\,\overline{(s^2 - b^2} \times \overline{b^2 - d^2)}^{\frac{1}{2}}.$$

THEOREM V.—To find the area of a polygon; the side, s, the number, n, of the sides of the polygon, and the radius, r, of the inscribed circle, being given:

$$\text{A} = \frac{rsn}{2}.$$

THEOREM VI. RULE 1.—To find the area of a circle; the diameter, d, and circumference, c, being given:

$$\frac{d}{2} \times \frac{c}{2}, \text{ or } \frac{dc}{4}.$$

THEOREM VII. RULE 2.—The diameter, d, being given:

$$.7854\,d^2.$$

THEOREM VIII. RULE 3.—The circumference, c, being given;

$$.0796\,c^2.$$

THEOREM IX.—To find the area of the sector of a circle, the radius, r, and the arc, a, being given:

$$\text{A} = r \times \frac{a}{2}, \text{ or } \frac{ra}{2}.$$

THEOREM X.—To find the area of a frustum sector, or part of a circular ring, contained between two radii; the breadth, b, the exterior arc, e, and interior arc, a, of the ring, being given:

$$\text{A} = b \times \frac{a+e}{2}.$$

THEOREM XI. RULE 1.—To find the area of the segment of a circle; the diameter, d, and the versed sine, v, being given:

$$\text{A} = 2v\,d^{\frac{1}{2}}v^{\frac{1}{2}} \times \left(\frac{2}{3} - \frac{v}{5d} - \frac{v^2}{28d^2} - \frac{v^3}{72d^3}\right), \text{ &c.}$$

Or thus, RULE 2.

$$2v\,d^{\frac{1}{2}}v^{\frac{1}{2}} \times \left(\frac{2}{3} - \frac{3v}{5.2d}\text{A} - \frac{5v}{7.4d}\text{B} - \frac{7.3v}{9.6d}\text{C} - \frac{9.5v}{11.8d}\text{D}, \text{ &c.}\right)$$

A, B, C, &c. being the first, second, third, &c. terms.

Or thus, RULE 3.

v being the supplemental versed sine, and $\text{v} = d - v$, therefore $d = \text{v} + v$; therefore $\text{A} = 2v\,\text{v}^{\frac{1}{2}}v^{\frac{1}{2}} \times \left(\frac{1}{1.1.3} + \frac{v}{1.3.5\,\text{v}} + \frac{v^2}{3.5.7\,\text{v}^2} + \frac{v^3}{5.7.9\,\text{v}^3}, \text{ &c.}\right)$

Or thus, RULE 4.—Where A, B, C, denote the preceding terms:

$$\text{A} = \frac{4}{3}v\,v^{\frac{1}{2}}\text{v}^{\frac{1}{2}} + \frac{v}{5\,\text{v}}\text{A} - \frac{1v}{7\,\text{v}}\text{B} + \frac{3v}{9\,\text{v}}\text{C} - \frac{5v}{11\,\text{v}}\text{D}, \text{ &c.}$$

THEOREM XII. RULE 5.—The chord, c, and versed sine, v, being given:

$$\text{A} = \frac{2cv}{3} + \frac{v^3}{2c}, \text{ or } v\left(\frac{2c}{3} + \frac{v^2}{2c}\right) \text{ or}$$

$$\text{A} = \frac{2cv}{3} + \frac{v^3}{2c} - \frac{v^6}{20c^4}, \text{ still nearer.}$$

THEOREM XIII. RULE 6.—The chord, C, of the half arc, and the versed sine, v, of the same, being given:

$$\text{A} = \left(\text{C} + \frac{4c}{3}\right) \times \frac{4}{10}v, \text{ or } c + \frac{4}{3}d^{\frac{1}{2}}v^{\frac{1}{2}} \times \frac{4}{10}v, \text{ by Sir Isaac Newton.}$$

THEOREM XIV. RULE 7.—The radius, r, the sine, s, and the versed sine, v, of half the arc, being given:

$$\text{A} = 11rs \times \frac{s^2 + v^2}{11s^2 + 3v^2}.$$

THEOREM XV.—To find the area of an ellipsis; the major axis, M, and the minor, m, being given:

$$\text{A} = .7854\,\text{M}\,m.$$

THEOREM XVI.—To find the area of an elliptic segment; the length, l, and the altitude, a, being given: also the breadth, b, of the segment of a circle of the same altitude and of the same diameter as the axis of the ellipsis, perpendicular to b.

$$\text{A} = \frac{l}{b} \times \left(\frac{2ab}{3} + \frac{a^3}{2c}\right).$$

THEOREM XVII.—To find the area of a parabola; the base, b, and the altitude, a, being given:

$$A = \frac{2ab}{3}.$$

THEOREM XVIII.—To find the area of the sinical curve; the radius, r, and the versed sine, v, of the segment, being given:

$$A = rv.$$

AREAS OF CURVED SURFACES.

THEOREM I.—To find the area of a cylindric surface; the axis, a, and the diameter, d, being given:

$A = 3.1416\,da$ in a right cylinder.

Or $A = pa$ in an oblique cylinder, where p is the perimeter.

THEOREM II.—To find the curved surface of a cylindric ungula, $A = \frac{ds - ac}{v}h$; where h is the length of the part that is cut, and v the versed sine of the segment which forms the base, and d the diameter.

THEOREM III.—To find the area of the curved surface of a right cone; the side, s, and the circumference, c, of the circumference, being given:

$$A = \frac{sc}{2}.$$

THEOREM IV.—To find the area of the segment of a square dome.

$A = 4(s^2 + v^2)$, or $4\,dv$; where s is the sine, and v the versed sine of the circular segment which forms the vertical section, or a the diameter of the circle which forms the vertical section.

THEOREM V.—To find the area of a segment of a hemisphere; given the radius, s, of the base, the versed sine, v, and the diameter, d, of the axal section:

$A = 3.1416\,(s^2 + v^2)$, or $3.1416\,dv$.

THEOREM VI.—To find the area of the frustum of the segment of a hemisphere; the circumference, c, of the great circle, and the distance, d, of the parallel planes, being given:

$$A = cd.$$

THEOREM VI'. RULE 1.—To find the surface of a spheroid; given the axis, and the diameter, d, of the great circle:

$A = .5236 \times (4ad + 2d^2)$.

Or, $A = 1.0472\,(2ad + d^2)$.

This is a near approximation.

THEOREM VIII. RULE 2.

$A = .8805\,(2ad + d^2) + \frac{a^2 + 2d^2}{6}$; still nearer to the truth than Rules 1 and 2.

THEOREM IX. RULE 1.—To find the surface of an ellipsoid; the length, a, the breath, b, and the thickness, c, being given:

$$2 \times .5236\,(ab + ac + bc).$$

This rule is a near approximation.

THEOREM X. RULE 2.

$A = .8805\,(ab + ac + bc) + \frac{a^2 + b^2 + c^2}{6}$; it is a nearer approximation than Rule 1.

THEOREM XI.—To find the surface of a semi-circular groin; given the side b.

$$A = 1.1416\,b^2.$$

SOLIDITIES OF BODIES.

THEOREM I.—To find the solidity of a cube.

$s = s^3$, where s is the linear dimension.

THEOREM II.—To find the solidity of a prism.

$s = ah$; where a is the area of the base, and h the perpendicular height. This also includes cylinders.

THEOREM III.—To find the solidity of a pyramid.

$s = \frac{ah}{3}$, or $\frac{h}{3} \times a$, or $\frac{a}{3} \times h$; where a is the area of the base, and h the perpendicular height. This also includes cones.

THEOREM IV.—To find the solidity of a wedge, or pyramoid; the two adjoining edges, a and b, of the base, the edge, c, in the same plane with a, and the height, being given:

$$s = \frac{2ab + cb}{6}h.$$

THEOREM V.—To find the solidity of the frustum of a pyramoid.

$s = \frac{ab + cd + 4ef}{6}h$; where a and c are the opposite terminations of a plane of one of the sides; b and d the opposite terminations of the plane of one of the adjoining sides; a and b being adjoining sides of the base, c and d those of the top, e the half sum of a and c, and f the half sum of b and d.

THEOREM VI.—To find the solidity of a cuneoid.

$s = \frac{2ab + cb}{6} \times .7854 \times h$. This formula is the same as that of Theorem V. except the additional multiplier .7854; this solid only differing in construction from the pyramoid in having elliptic sections instead of rectangular ones.

THEOREM VII.—To find the solidity of the frustum of a cuneoid.

$s = \frac{ab + cd + 4ef}{6} \times .7854 \times h$; where a and c are the two axes of the elliptic base, and c and d the axes of the elliptic top; c being opposite to a, and d opposite to b. This solid only differs from the frustum of a pyramoid in being circular.

THEOREM VIII.—To find the solidity of the segment of a cylinder.

RULE 1.—$s = al\left(\frac{2b}{3} + \frac{a^2}{2b}\right)$; where a is the versed sine, b the chord of the base, and l the length of the cylinder.

RULE 2.—$s' = l \times \left(\frac{ab + a^2}{2} + \frac{b^2}{56}\right)$; still nearer than RULE 1. when the segment is nearly a semi-cylinder.

THEOREM IX.—To find the solidity of the segment of a square dome.

RULE 1.—$s = 4rx^2 - \frac{4x^3}{3}$; where x is the height, and r the radius of the circle, of which the segment forming the vertical section is a part. *See* vol. i. p. 284 of this Work.

RULE 2.—$s = \frac{as^2}{2} + \frac{2a^3}{3}$; where s is the side of the square base, and a the altitude of the dome. *See* vol. i. p. 286 of this Work.

THEOREM X.—To find the solidity of the segment of a hemisphere.

RULE 1.—$s' = p\left(r x^2 - \frac{x^3}{3}\right)$; where p is equal to $4 \times .7854 = 3.1416$; and x and r, as in the preceding Theorem.

RULE 2.—$s = .7854\left(\frac{a s^2}{2} + \frac{2 a^3}{3}\right)$.

This only differs from RULE 2. THEOREM IX. in the base being circular. It gives the contents independent of the diameter of the great circle.

THEOREM XI.—To find the solidity of a truncated square dome, independent of the radius, or diameter, of the vertical section.

$s = a s^2 - \frac{4 a^3}{3}$; where a is the altitude, and s the side, of the square base.

THEOREM XII.—To find the solidity of the frustum of a hemisphere.

$s = .7854\left(a s^2 - \frac{4 a^3}{3}\right)$; being the same as in the last Theorem, except the multiplier .7854.

THEOREM XIII.—To find the solidity of a hollow truncated square dome.

$s = a\,(D^2 - d^2)$; where D is the side of the square base, between the opposite external surfaces, d the side of the square base between the opposite internal surfaces, and a the altitude; supposing the heel to be equally thick.

THEOREM XIV.—To find the solidity of a hollow hemispheric frustum.

$.7854\ a\ (D^2 - d^2)$; being the same as Theorem XIII., excepting the multiplier .7854.

THEOREM XV.—To find the solidity of a paraboloid.

$s = \frac{b h}{2}$; where h is the height, and b the area of the base.

THEOREM XVI.—To find the solidity of the frustum of a paraboloid.

$s = \frac{a + b}{2} h$; where a and b are the areas of the two ends.

THEOREM XVII.—To find the solidity of an hyperboloid.

$s = \frac{a + b + 4 m}{6} h$; where a and b are the areas of the two ends, and m the area of the middle section. This theorem will also serve to measure a sphere, spheroid, paraboloid, cone, pyramid, pyramoid, or any segment, or frustum of these bodies.

Notes on the preceding Theorems.

RECTIFICATION OF CURVES.

RULE 2, of THEOREM VII. by Huygens, is very neatly expressed by $\frac{8 h - c}{3}$; but the half chord must either be found geometrically, by bisecting the chord by a perpendicular, and drawing the half chord, or by a very operose arithmetical operation. If $d = 2 h - c$, then will $c + d + \frac{d}{3}$ be the length of the arc: this affords a very easy geometrical construction; viz., *if to the chord of the whole arc be added the difference of twice the chord of the half arc and the chord of the whole arc, and one-third of the said difference, the sum will be nearly the length of the arc, for* $c + d + \frac{d}{3} = c + (2 h - c) + \frac{2 h - c}{3} = \frac{8 h - c}{3}$.

RULES 3, 4, 5, 6. THEOREMS VII. VIII. IX. and X. were invented by Mr. Nicholson. The circumstance which gave rise to them was a stone weir, or dam, which he had designed and superintended at Denton Holm Head, over the river Caldew, near Carlisle. The form of the weir was that of the segment of a circle, of which the chord was 200 feet, and the versed sine 22 feet; when the work was completed, the contractor for the mason's work was very desirous to have it measured, but at that time, being early in the spring of 1810, the river was flooded so high, that the water ran two feet above the top of the weir; now having the true dimensions, as above, and an exact section of the work, it was only necessary to find the length of the arc, and then the solid contents were easily computed: but, in order to obtain this end, he found that the calculations by the rule of Huygens would require too much trouble for common business, and therefore, as well for present convenience as for anything that might happen in future of a like nature, the following formulas were invented: $L = c \frac{6 d - v}{6 d - 5 v}$,

$$\text{or } L = c + \frac{4 v c}{6 d - 5 v} = c \frac{3 c^2 + 10 v^2}{3 c^2 + 2 v^2},$$

$$\text{or } L = c + \frac{8 v^2 c}{3 c^2 + 2 v^2} = c \frac{6 s^2 + 5 v^2}{6 s^2 + v^2},$$

$$\text{or } L = c + \frac{4 v^2 c}{6 s^2 + v^2}.$$

The second formula, or Rule 4, is derived from the first, by substituting the value of d in terms of c and v; and Rule 5 is also derived from Rule 3, by substituting the value of d in terms of s and v; so that, being derived from each other, they will all give the very same result; and to show how near this is to the truth, the investigation is as follows:

For $c \frac{6 d - v}{6 d - 5 v} = 2 (d v - v^2)^{\frac{1}{2}} \times \frac{6 d - v}{6 d - 5 v}$, the quantity $2 (d v - v^2)^{\frac{1}{2}}$, being the value of c, in terms of d and v:

but $2 (d v - v^2)^{\frac{1}{2}} = 2 d^{\frac{1}{2}} v^{\frac{1}{2}} \times \left(1 - \frac{v}{2 d} - \frac{v^2}{8 d^2}, \text{ &c.}\right)$

and $\frac{6 d - v}{6 d - 5 v} = 1 + \frac{2 v}{5 d} + \frac{5 v^2}{9 d^2}$, &c.

Hence $2 (d v - v^2)^{\frac{1}{2}} \times \frac{6 d - v}{6 d - 5 v} = 2 d^{\frac{1}{2}} v^{\frac{1}{2}} \times$

$$\left(1 - \frac{v}{2 d} - \frac{v^2}{8 d^2}, \text{ &c.}\right) \times \left(1 + \frac{2 v}{3 d} + \frac{5 v^2}{9 d^2}, \text{ &c.}\right)$$

$$= 2 d^{\frac{1}{2}} v^{\frac{1}{2}} \times \left(1 + \frac{v}{6 d} + \frac{7 v^2}{72 d^2}, \text{ &c.}\right)$$

but $2 d^{\frac{1}{2}} v^{\frac{1}{2}} \times \left(1 + \frac{v}{6 d} + \frac{3 v}{40 d^2}, \text{ &c.}\right)$ is known to express the arc of a circle, whose diameter is d, and its versed sine v; now this last series only differs from the former in the third term, in being less; the excess being $\frac{v}{45 d^2}$.

Now, to show how far these rules may be depended upon in practice, Mr. Nicholson calculated the following table,

where the numbers found answer to segments of different proportions. The results found, both by Huygens' rule and by that of Nicholson, are compared with the result found by an infinite series, which is the criterion; because, by such an infinite series the answer may be found, which can be depended upon, to any number of figures. The result found by the series in the table is therefore true to the last figure, or to the last but one when the next figure would be above 5. In this case. the last figure of the decimal is augmented by unity.

In the table, the first vertical column contains the chords, and is marked C; the second column contains the versed sines of the several segments, and is marked V; the third column contains the lengths of the arcs, according to the dimensions stated in columns C and V in the same horizontal row, and is marked L; and the last column, marked R, shows the ratio, or number of times that the versed sine is contained in the chord. In each cell under L are the three results; the upper one being that of Huygens, the middle one that of the series, and the lower one that of Nicholson.

C	V	L	R
936	155	1002.666 1002.959 1002.9	$6\frac{6}{135}$
24	5	26.666 26.687 26.69	$4\frac{4}{5}$
556	136	631.333 632.252 632.5	$4\frac{1}{68}$
8	3	10.666 10.724 10.743	$2\frac{2}{3}$
240	119	370.666 374.960 375.24	$2\frac{2}{119}$
14	7	21.73 21.991 22.	2

From this table it appears, that in low segments the result is nearly the same by each rule, but that Nicholson's is nearer to the series than that of Huygens; and it becomes much more so in proportion as the segment approaches towards a semicircle: thus, in a semicircle, the length of the arc found by the series is 21.991; the length found by Huygens is 21.73; the difference .261. Now, the length of the arc found by Nicholson's rule is 22, which is ultimately the Archimedean proportion, and the difference between this result and that found by the series is only .009.

In the first horizontal row, both methods agree with the series to four places of figures; in the second, they agree in three places; in the third, fourth, and fifth, they agree in two places; and in the sixth they agree in one. In the first horizontal column, Nicholson's method agrees in five places with the series; in the second, third, and fourth, with three figures of the series; in the fifth, with two figures of the series, and in the last with one figure of the series; but only differs in five figures from the truth by .009.

The length of the arc found by the two approximating rules in low segments, is exceedingly near the true value; but when the result is found by Huygens' rule in high segments, it is very considerably below it, and cannot well be employed in large dimensions.

There is still another rule to be found in books of mensuration, which will give the length of the arc to any exactness, either by finding the number of degrees by means of an instrument, or by trigonometry; the former is not very eligible in practice, and the latter would require too much time to be of real utility amid the hurry of business.

The investigation of Rule 6, Theorem X., from the geometrical division of the arc of the circle into equal parts, by the diameter being divided also into equal parts, is as follows:

Let A D B C be a circle; A B and C D two diameters, intersecting each other in E at right angles; let the diameter, D C, be produced to F, so that the part, C F, without the circle may be three-quarters of the radius, E C, or three-eighths of the diameter, D C; draw D G parallel to A B; take any portion, D I, of the arc D A; join F I; and produce F I to G:

Let D C be denoted by d; then will $FD = d + \frac{3d}{8} = \frac{11d}{8}$;

and $FK = FD - KD = \frac{11d}{8} - v = \frac{11d - 8v}{8}$.

Now, the triangles F K I and F D G are similar; therefore FK : FD :: KI : DG;

that is, $\frac{11d - 8v}{8} : \frac{11d}{8} :: s : DG = \frac{11ds}{11d - 8v}$; which is the value of the tangent.

Then, to show how nearly this value is to that of the arc, we have $\frac{11ds}{11d - 8v} = \frac{s}{1 - \frac{8v}{11d}}$;

but $s = (dv - v^2)^{\frac{1}{2}} = d^{\frac{1}{2}} v^{\frac{1}{2}} \left(1 - \frac{v}{2d} - \frac{v^2}{8d^2}, \&c.\right)$

therefore $\frac{s}{1 - \frac{8v}{11d}} = d^{\frac{1}{2}} v^{\frac{1}{2}} \times \frac{1 - \frac{v}{2d} - \frac{v^2}{8d^2}, \&c.}{1 - \frac{8v}{11d}} = d^{\frac{1}{2}} v^{\frac{1}{2}} \times \left(1 + \frac{5v}{22d} + \frac{39v^2}{968d^2}, \&c.\right)$ the value of

the tangent, which should be equal to that of the arc; but the series expressed in the same terms for the value of the arc, is $d^{\frac{1}{2}} v^{\frac{1}{2}} \times \left(1 + \frac{v}{6d} + \frac{3v^2}{40d^2}, \&c.\right)$ it therefore appears that the value of the tangent is too great to express the value of the arc.

The length of the arc may be ascertained with tolerable exactness by Theorems XII. and XIII., which are thus expressed:—$z = c + \frac{cv}{3} + \frac{v^3}{cr}$, or $2s + \frac{cv}{3} + \frac{2v^4}{s^2 + v^2}$, by substituting $\frac{s^2 + v^2}{2v}$ for r, and $2s$ for c, in the first formula.

This rule gives the length of the arc 10.73, when the chord is 8 and the versed sine 3; and the series gives 10.724; and in a semicircle, where the chord is 14 and the versed sine 7, the length of the arc will be 22.16; the proportion of Archimedes would give 22. As this rule depends upon the area of the segment, the investigation will be given under that of Rule 7, Theorem XI, of the areas of plane figures, which follows.

Areas of Plane Figures.

Theorem XII. Rule 5, is a very near approximation to the quadrature of the segment of a circle. It is much easier than any other rule yet shown for the same purpose. It was invented, and first published in the article Mensuration, of *The principles of Architecture*, by Nicholson; since that time, it has been copied into the new edition of Hawney's *Mensuration*. The rule was first given without a demonstration; but it is now supplied with the following investigation.

The expression for the area is $\frac{2cv}{3} + \frac{v^3}{2c}$, where c is the chord, and v the versed sine.

Now, $c = 2(dv - v^2)^{\frac{1}{2}} = 2d^{\frac{1}{2}} v^{\frac{1}{2}} \times \left(1 - \frac{v}{d}\right)^{\frac{1}{2}} = 2d^{\frac{1}{2}} v^{\frac{1}{2}} \times \left(1 - \frac{v}{2d} - \frac{v^2}{8d^2}, \&c.\right)$

therefore $\frac{2cv}{3} = \frac{4d^{\frac{1}{2}} v^{\frac{1}{2}}}{3} \times \left(1v - \frac{v^2}{2d} - \frac{v^3}{8d^2}, \&c.\right)$

$\frac{1}{c} = \frac{1}{2d^{\frac{1}{2}} v^{\frac{1}{2}}} \times \left(1 - + \frac{v}{2d} + \frac{3v^2}{8d^2}, \&c.\right)$

Therefore $\frac{v^3}{2c} = \frac{v^3}{4d^{\frac{1}{2}} v^{\frac{1}{2}}} \times 1 + \frac{v}{2d} + \frac{3v^2}{8d^2}, \&c.$

Hence $\frac{2cv}{3} + \frac{v^3}{2c} = \frac{4d^{\frac{1}{2}} v^{\frac{1}{2}}}{3} \times v - \frac{v^2}{2d} - \frac{3v^3}{8d^2}, \&c. + \frac{v^3}{4d^{\frac{1}{2}} v^{\frac{1}{2}}} \times 1 + \frac{v}{2d} + \frac{3v^2}{8d^2}, \&c.$

Now let the last equation be multiplied by $d^{\frac{1}{2}} v^{\frac{1}{2}}$.

Then $d^{\frac{1}{2}} v^{\frac{1}{2}} \left(\frac{2cv}{3} + \frac{v^3}{2c}\right) = \frac{4dv}{3} \times \left(v - \frac{v^2}{2d} - \frac{v^3}{8d^2}, \&c.\right) + \frac{v^3}{4} \times \left(1 + \frac{v}{2d} + \frac{3v^2}{8d^2}, \&c.\right)$

$= \frac{4dv^2}{3} - \frac{4v^3}{6} - \frac{4v^4}{24d}, \&c. + \frac{v^3}{4} + \frac{v^4}{8d} + \frac{3v^5}{32d^2}, \&c.$

$= \frac{4dv^2}{3} - \frac{5v^3}{12} - \frac{v^4}{24d}, \&c.$

Now let this last equation be divided by $d^{\frac{1}{2}} v^{\frac{1}{2}}$,

and we obtain $\frac{2cv}{3} + \frac{v^3}{2c} = \frac{1}{d^{\frac{1}{2}} v^{\frac{1}{2}}} \times \left(\frac{4dv^2}{3} - \frac{5v^3}{12} - \frac{v^4}{24d}, \&c.\right)$

or $\frac{2cv}{3} + \frac{v^3}{2c} = \frac{1}{d^{\frac{1}{2}} v^{\frac{1}{2}}} \times \frac{d^{\frac{1}{2}} v^{\frac{1}{2}}}{d^{\frac{1}{2}} v^{\frac{1}{2}}} \times \left(\frac{4dv^2}{3} - \frac{5v^3}{12} - \frac{v^4}{24d}, \&c.\right)$

or $\frac{2cv}{3} + \frac{v^3}{2c} = \frac{d^{\frac{1}{2}} v^{\frac{1}{2}}}{dv} \times \left(\frac{4dv^2}{3} - \frac{5v^3}{12} - \frac{v^4}{24d}, \&c.\right)$

or $\frac{2cv}{3} + \frac{v^3}{2c} = d^{\frac{1}{2}} v^{\frac{1}{2}} \times \left(\frac{4v}{3} - \frac{5v^2}{12d} - \frac{v^3}{24d^2}, \&c.\right)$

or $\frac{2cv}{3} + \frac{v^3}{2c} = d^{\frac{1}{2}} v^{\frac{1}{2}} \times \left(\frac{4v}{3} - \frac{10v^2}{24d} - \frac{2v^3}{48d^2}, \&c.\right)$

or $\frac{2cv}{3} + \frac{v^3}{2c} = 2v \times d^{\frac{1}{2}} v^{\frac{1}{2}} \times \left(\frac{2}{3} - \frac{5v}{24d} - \frac{v^2}{48d^2}, \&c.\right)$

But $2v \times d^{\frac{1}{2}} v^{\frac{1}{2}} \times \left(\frac{2}{3} - \frac{v}{5d} - \frac{v^2}{28d^2}, \&c.\right)$ is known to be the value of the segment, the diameter of which is d, and its versed sine v; then by comparing these two series they will be found to be nearly equal, the former being the greater;

for the first term is $\frac{2}{3}$ in both, and the second term in the approximation only differs from that of the proper series by a quantity less than $\frac{v}{120\,d}$.

From this Theorem, $\frac{2\,c\,v}{3} + \frac{v^3}{2\,c}$, we may derive $c + \frac{c\,v}{3} + \frac{v^3}{c\,r}$, as in Theorem XI. Rule 7, for the rectification of curves.

In the sector A D C E A draw the chord A C and E D perpendicular to A C, cutting A C at B; let A C′ = c, and B D = v; then B E = D E − D B = $r - v$; consequently the area of the triangle A C E = $\frac{r-v}{2} \times c = \frac{c\,r - c\,v}{2}$; but the area of the segment A D C is $\frac{2\,c\,v}{3} + \frac{v^3}{2\,c}$; therefore the area of the sector A D C E A is equal to $\frac{2\,c\,v}{3} + \frac{v^3}{2\,c} + \frac{c\,r - c\,v}{2} = \frac{c\,v}{6} + \frac{v^3}{2\,c} + \frac{c\,r}{2}$; and if this area be divided by the radius, we obtain $\frac{c\,v}{6\,r} + \frac{v^3}{2\,c\,r} + \frac{c}{2}$, or $\frac{c}{2} + \frac{c\,v}{6\,r} + \frac{v^3}{2\,c\,r}$ for the half arc, or $c + \frac{c\,v}{3\,r} + \frac{v^3}{c\,r}$, for the whole arc. And if $\frac{c^2 + 4\,v^2}{8\,v}$ be substituted for r, we obtain $c + \frac{8\,c\,v^2}{3\,c^2 + 12\,v^2} + \frac{8\,v^4}{c^3 + 4\,c\,v^2}$ for the value of the arc in terms of c and v.

Theorem XIV. Rule 7, of the areas of plane figures, $11\,r\,s \times \frac{s^2 + v^2}{11\,s^2 + 3\,v^2}$, being the area of the segment, the sine of the half arc of which is s, the versed sine v, and the radius r, evidently follows from Theorem X. Rule 6, by multiplying half the arc, $\frac{11\,s}{2} \times \frac{s^2 + v^2}{11\,s^2 + 3\,v^2}$, by the radius r.

Theorem XVI. being $\frac{l}{b} \times \left(\frac{2\,a\,b}{3} + \frac{a^3}{2\,b}\right)$ will easily be obtained from the following consideration, viz., suppose the ellipsis to be completed, and a circle to be described upon the axis, which bisects the base of the elliptic segment; then let the base of the elliptic segment, to be continued, if necessary, meet the circumference of the circle on each side; then it will be as the base of the circular segment is to the base of the elliptic segment, so is the area of the circular segment to the area of the elliptic segment; therefore, if the area of the circular segment be known, that of the elliptic segment will follow; now the area of the circular segment is $\frac{2\,a\,b}{3} + \frac{a^3}{2\,b}$; therefore, $b : l :: \frac{2\,a\,b}{3} + \frac{a^3}{2\,b} : \frac{l}{b} \times \left(\frac{2\,a\,b}{3} \times \frac{a^3}{2\,b}\right)$ the area of the elliptic segment.

Areas of Curved Surfaces.

Theorem VII. Rule 1, is an approximation; and the following will show what dependence is to be placed in the result obtained by calculation.

Let a = the axis of the spheroid;
b = the diameter of the great circle;
and x = an indefinitely small distance, compared with a or d.

Now .5236 $a\,d^2$ is the expression for the solidity of the spheroid, being two-thirds of its circumscribing cylinder;

then $(d + x)^2 \times (a + x) = a\,d^2 + 2\,a\,d\,x + a\,x^2 + d^2\,x + 2\,d\,x^2 + x^3 = a\,d^2$ nearly, being in excess;
and $(d - x) \times (a - x)$ $a\,d^2 - 2\,a\,d\,x + a\,x^2 - d^2\,x + 2\,d\,x^2 - x^3 = a\,d^2$ nearly, being in defect;
therefore $4\,a\,d\,x + 2\,d^2\,x + 2\,x^3$ will be the solidity of a thin shell, the thickness of which is x; therefore $4\,a\,d + 2\,d^2 + 2\,x^2$ will be the area of such a shell, or $4\,a\,d + 2\,d^2$, by leaving out the quantity $2\,x^2$, which is indefinitely small: therefore .5236 $(4\,a\,d + 2\,d^2)$ is the area of a spheroid nearly; it is exactly so when a and d are equal; for then .5236 $(4\,a\,d + 2\,d^2)$ becomes $5236 \times 6\,d^3 = 4 \times .7854\,d^3$, but the greater the difference between a and d, the more will the error be; because the thin shell varies more in its thickness.

Corollary 1.—Hence the surface of every rectangular prism with a square base is $4\,a\,d + 2\,d^2$.

Corollary 2.—When a = nothing, then .5236 $(4\,a\,d + 2\,d^2)$ becomes .5236 $\times\ 2\,d^2 = 1.0472\,d^2$, instead of .7854 d^2, the area of the base.

Example for the Oblong Spheroid.

50 = a	40 = d
40 = d	40 = d
2000 = $a\,d$	1600 = d^2
4	2
8000 = $4\,a\,d$	3200
3200	
11200 = $4\,a\,d + 2\,d^2$	

.5236
11200
1047200
5236
5236
5864.3200 = .5236 $(4\,a\,d + 2\,d^2)$.

The true answer is 5882.6385, the difference is therefore only 18.3185, which is not worth regarding in so large a number. In a dome which is the half of an oblong spheroid, the error would only be 9.1592 less than the truth.

Example for an Oblate Spheroid.

40 = a	50
50 = d	50
2000 = $a\,d$	2500 = d^2
4	2
8000 = $4\,a\,d$	5000
5000	
13000 = $a\,d + 2\,d^2$	

.5236
13000

15708000
5236

6806.8000 $= .5236\ (4\,a\,d + 2\,d^2)$

The answer ought to be 6830.4507; the error being about ·24 less than the truth, which is very trifling in so great a number.

In architecture, we very seldom have domes of such large dimensions; and the value of a foot of plaster, or painting, can never be of any great consequence. This rule will therefore be sufficient for every practical purpose.

The following table contains the areas of the curved surfaces of spheroids of various proportions, according to the formula $.5236 \times (4\,a\,d + d^2)$ and to the real series; the comparison of the results will enable us to judge of the truth of the answer as found by the formula.

Rules.	A	D	Area.	Difference.
Series.....	40	40	5026.56	none, being equal.
Formula....	40	40	5026.56	
Series.....	50	40	5882.63	18.31 defective.
Formula....	50	40	5864.32	
Series.....	60	40	6867.30	65.22 defective.
Formula....	60	40	6702.08	

Let us now try if any addition can be made to amend the above formula, which always gives the result less than the truth. We know, that the quantity to be added must be equal to nothing, when a is equal to d; we also know that the sum of the squares of two quantities is greater than twice their product; and when these quantities are equal, that the sum of their squares and twice their product will be equal: therefore $a^2 + d^2$ is greater than $2\,a\,d$; and the greater the difference between a and d, the more the sum of the squares of a and d will exceed twice the product, $2\,a\,d$, of a and d: thus, when one of the quantities, as d, is nothing in the sum, $a^2 + d^2$, of the squares, the quantity a^2 only remains, and in twice the product $2\,a\,d$, the whole vanishes. Therefore the value of $a^2 + d^2 - 2\,a\,d$ will be greater, as the difference between a and d is greater.

But to show what this difference is, by finding the value of these quantities in the same terms:

Let the greater, $d = a + x$;
then $d^2 = a^2 + 2\,a\,x + x^2$;
and $a^2 + d^2 = 2\,a^2 + 2\,a\,x + x^2$.
Again, $2\,a\,d = 2\,a\,(a + x) = 2\,a^2 + 2\,a\,x$:

now $2\,a^2 + 2\,a\,x + x^2$ is greater than $2\,a^2 + 2\,a\,x$ by x^2; that is, the sum of the squares, $a^2 + d^2$, of a and d, is greater than $2\,a\,d$ by the square of the difference of a and d; therefore the value of $a^2 + d^2 - 2\,a\,d$ will be greater, as a is greater than d. But to show that the square of the difference will not be very great in common cases, let $a = 4$, and $d = 3$, then the square of the difference is only 1; that is, when the difference is 1, the square of the difference will also be 1.

Let us now return to the subject, by adding the quantity proposed to $.5236\ (4\,a\,d + 2\,d^2)$; it will be found by adding $a^2 + d^2 - 2\,a\,d$ to $.5236\ (4\,a\,d + 2\,d^2)$ that the sum will be too great; therefore let the quantity $a^2 + d^2 - 2\,a\,d$ be divided by some number: on trial it appears that the addition of $\frac{a^2 + d^2 - 2\,a\,d}{6}$ to $.5236\ (4\,a\,d + 2\,d^2)$ will give a result very near to the truth, at the same time that it furnishes a very easy formula for architectural purposes, in the mensuration of domes, as will be seen in the following table.

This formula will therefore now stand $.5236\ (4\,a\,d + 2\,d^2) + \frac{a^2 + d^2 - 2\,a\,d}{6} = 1.0472\ (4\,a\,d + 2\,d^2) + \frac{a^2 + d^2 - 2\,a\,d}{6}$, which may again be reduced to this form $.8805\ (2\,a\,d + d^2) + \frac{a^2 + 2\,d^2}{6}$.

Rules.	A	D	Areas.	Difference.
Series.....	40	40	5026.56	nothing.
Formula....	40	40	5026.56	
Series.....	50	40	5882.63	1.83 in defect
Formula....	50	40	5880.8	
Series.....	60	40	6767.30	1.44 in excess.
Formula....	60	40	6768.74	

This table shows the formula sufficiently exact for any practical purpose, at least in all useful propositions of architecture; and therefore confirms Theorem VIII. Rule 2. If a dome upon an elliptic plan, rising half the minor axis, be required to be measured, then the rule for such a dome will be $.4402\ (2\,a\,d + d^2) + \frac{a^2 + 2\,d^2}{12}$.

The approximating formula $2 \times .5236\ (a\,b + a\,c + b\,c)$, Theorem IX. Rule 1, may be thus confirmed: let the three dimensions of the ellipsoid be a, b, c, and let x be a very small increment to be added to a, b, and c, respectively; also a very small decrement to be taken from a, b, and c, respectively; now the solidity of an ellipsoid is $.5236\ a\,b\,c$; then

$a\,b\,c = (a + x) \times (b + x) \times (c + x) = a\,b\,c + b\,c\,x + a\,c\,x + c\,x^2 + a\,b\,x + b\,x^2 + a\,x^2 + x^3$, nearly;
and $a\,b\,c = (a - x) \times (b - x) \times (c - x) = a\,b\,c - b\,c\,x - a\,c\,x + c\,x^2 - a\,b\,x + b\,x^2 + a\,x^2 - x^3$, nearly;
therefore $2\,b\,c\,x + 2\,a\,c\,x + 2\,a\,b\,x + 2\,x^3$ is the increment of the solid, or the solidity of a shell, the thickness of which is x; consequently, if the increment, $2\,b\,c\,x + 2\,a\,c\,x + 2\,a\,b\,x$, of the solid be divided by x, we shall then obtain $2\,b\,c + 2\,a\,c + 2\,a\,b + 2\,x^3$ for the surface of the solid; but the quantity $2\,x^3$ is indefinitely small, and appears as nothing in comparison of $2\,b\,c + 2\,a\,c + 2\,a\,b$; therefore $2\,b\,c + 2\,a\,c + 2\,a\,b$, or $2\,a\,b + 2\,a\,c + 2\,b\,c$ is nearly equal to the surface of the solid; and consequently, $.5236\ (2\,a\,b + 2\,a\,c + 2\,b\,c)$, or $1.0472\ (a\,b + a\,c + b\,c)$ will be nearly equal to the surface of the ellipsoid.

Corollary 1.—Hence $2\,a\,b + 2\,a\,c + 2\,b\,c$ will be the surface of a rectangular prism, exactly.

Corollary 2.—Let a, b, and c, be each equal to d; then $1.0472\ (a\,b + a\,c + b\,c)$ becomes $1.0472 \times 3\,d^2 = 3.1416\ d^2 = 4 \times .7854\ d^2$, as it ought to be: but the greater the difference between a, b, and c, the more will the error be.

This rule may be corrected in the same manner as Theorem VII. Rule 1; by adding $\frac{a^2 + b^2 + c^2 - a\,b - a\,c - b\,c}{6}$; which

being done, the formula may be reduced to .8805 $(ab + ac + bc) + \frac{a^2 + b^2 + c^2}{6}$, which gives Theorem X. Rule 2.

Notes on the Solidities of Bodies.

The method of the middle section has never been noticed by any writer in a practical way. There can be little doubt but this method took its rise from that of equidistant ordinates, first given by Sir Isaac Newton, as we are informed by Shirtcliffe, in his *Art of Gauging*, in the following words:

"I shall lay down a proposition for measuring planes or solids by approximation, a thing of the greatest importance to this part of science, of any that was ever brought for that purpose, since it may be said to contain the whole art of gauging, and that of coppers, stills, tuns, as well as all kinds of casks, whether full or partly empty, either standing or lying.

"*Of measuring curvilinear planes and solids, by approximation.*

"Proposition.—If MQ = y', NR = y'', PS = y''' represent three equidistant perpendicular ordinates to the axis of a curve, MNP, whose equation is $y = a + bx + cx^2$, where x stands for any abscissa, QT, and y its ordinate, TO; then, calling QS the distance of the extreme ordinates, l, the measure of the space, QMPS, will be thus expressed:

"Theorem. $QMPS = \overline{y' + y''' + 4y''} \times \frac{l}{6}$.

"For by the preceding principles, the quadrature of the curve, whose abscissa is x, and ordinate $a + bx + cx^2$, will be found $a + \overline{\frac{bx}{2} + \frac{cx^2}{3}} \times x$; and this, when x becomes l, is

$$\overline{a + \frac{bl}{2} + \frac{cl^2}{3}} \times l = \overline{6a + 3bl + 2c^2} \times \frac{l}{6}, = QMPS.$$

But from the equation of the curve we have these three equations,

$$y' = a;$$
$$y'' = a + \frac{bl}{2} + \frac{cl^2}{4};$$
$$y''' = a + bl + cl^2.$$

And by taking the difference of those above, we have

$$y - a = \frac{bl}{2} + \frac{cl^2}{4};$$
$$y''' - y'' = \frac{bl}{2} + \frac{3cl^2}{4}.$$

And the difference of the last gives

$$y''' - 2y'' + a = \frac{cl}{2}.$$

Whence $2cl^2 = 4 \times \overline{y''' - 2y' + a}$; and by the third equation above, $bl = \overline{y''' - a - cl^2}$; therefore $3bl = 3y''' - 3a - 6 \times \overline{y''' - 2y'' + a} = -3y''' + 12y'' - 9a$; put these for $2cl^2$ and $3bl$, in the above expression of the area, and then we have, QMPS, $= \overline{6a + 3bl + 2cl^2} \times \frac{l}{6} = y' + 4y'' + y''' + \frac{l}{6}$. Q. E. D.

"Corollary 1.—The same method of demonstration extends to any number of equidistant ordinates; so if A denotes the sum of the extreme ordinates, B the sum of those next to them, C the sum of the two next following the last, and so on; then we shall have the following tables of areas, for the several numbers of ordinates prefixed to them, viz., for

2. $A \times \frac{l}{2}$;

3. $\overline{A + 4B} \times \frac{l}{6}$;

4. $\overline{A + 3B} \times \frac{l}{8}$;

5. $\overline{7A + 32B + 12C} \times \frac{l}{90}$;

6. $\overline{19A + 75B + 50C} \times \frac{l}{288}$;

7. $\overline{41A + 216B + 27C + 272D} \times \frac{l}{840}$;

8. $\overline{751A + 3577B + 1323C + 2989D} \times \frac{l}{17280}$ &c. &c.

"This method was invented by Sir Isaac Newton, and published by Mr. Jones in 1711; and since prosecuted by Mr. Coats, Mr. De Moivre, and by Mr. Stirling, in a whole treatise entirely built thereon, where such as desire a farther insight into this matter, may find it sufficiently explained, and applied to some of the most intricate parts of mathematics."

This table errs in the last term of the areas corresponding to the ordinates 3, 5, 7, &c., viz., 4B should only be 2B, and 12C should only be 6C, and so of the rest; that is, they are double what they ought to be.

This error has also escaped the notice of that great mathematician, Mr. Emerson, see p. 29 of his *Differential Method*, published with his *Conic Sections*, 1767, where he has the same table as in *Shirtcliffe's Gauging*; but it has been corrected by Dr. Hutton. *See* his *Mensuration*, large copy, printed in 1770.

To show how this rule may be derived in the simplest manner, in order to approximate any curvilinear surface, of which the ends are parallel, let AEDBA be bounded on one side by a parabolic curve, BCD; and let AB and ED be two diameters, or straight lines, parallel to its axis; and let AE be perpendicular to AB and ED; also let AE be bisected in F; and let FC be drawn parallel to AB or ED; and let BD be drawn cutting FC in G;

and let AB = q,
FC = b,
and ED = c;
also, AF, or FE = m:

now FG will be equal to $\frac{a+c}{2}$,

and the part GC will be $b - \frac{a+c}{2}$.

but the space BCDB is equal to a parabola, of which the base is AE, or $2m$, and the height GC, or $b - \frac{a+c}{2} = \frac{2b-a-c}{2}$;

therefore $\frac{2}{3} + \text{G C} \times \text{A E} = \frac{2}{3} \times \frac{2b - a - c}{2} \times 2m =$ $\frac{2m}{3} \times (2b - a - c)$ the area B C D B; but the area of the trapezoid A B D E is equal $\frac{1}{2} \times (a + c) \times 2m = (a + b) \times m$; therefore the area A B C D E A $= (a + c) \times m +$ $(2b - a - c) \times \frac{2m}{3} = \left(a + c + \frac{4b - 2a - 2c}{3}\right) \times m$ $= \frac{3a + 3c + 4b - 2a - 2c}{3} \times m = \frac{a + c + 4b}{3}$ $\times m$, or $\frac{a + 4b + c}{3} \times m$.

Now, let A B C D E F G, &c. be the abscissa of a curve, H I J K L M N, &c. and let A H, B I, C J, be any number of even equidistant ordinates, and let these ordinates be denoted by a, b, c, d, e, f, g, &c. Let us suppose a parabolic curve to pass through every adjoining three; that is, taking in every two adjoining spaces; and let m be the common breadth of every space; then the area of the first two spaces will be $\frac{a + 4b + c}{3} \times m$; the area of the two next spaces will be $\frac{c + 4d + e}{3} \times m$; the area of the two next spaces will be $\frac{e + 4f + g}{3} \times m$, and so on, as far as we please. Now the sum of all these areas will be the area of the whole curve; therefore, $\frac{a + 4b + c}{3} \times m + \frac{c + 4d + e}{3} \times m +$ $\frac{e + 4f + g}{3} \times m$, &c. $= \frac{4b + 4d + 4f + 2c + 2e + a + g}{3}$ $\times m = \frac{4 \times (b + d + f) + 2 \times (c + e) + a + g}{3} \times m$ equal to the area of the curve.

This not only holds true in superficies, but also in solids.

Then, if the intermediate ordinates be called sections, and be numbered 1, 2, 3, &c., the first being called odd, the next even, and so on alternately; the last section will always be odd; then to four times the sum of the odd sections add twice the sum of the even sections, and the two ends; then one-third of the sum being multiplied by the common distance gives the area, which is a near approximation for any curvilinear figure whatever.

Observations on Averaging Surfaces, bounded on one or on two opposite sides by a Curve.

In the mensuration of superficies bounded by curves, the common method of taking the average, or mean, of any number of ordinates, by adding all the ordinates together, and dividing by their number, and multiplying the quotient by the length, is extremely vague.

For let the figure proposed to be measured be A E F H K A, divided by the equidistant ordinates B I, C H, D G. Let A K be denoted by a, B I by b, C H by c, D h by d, E F by e; and let the common distance, A B, or B C, &c., be denoted by m; and let each of the areas, A B I K A, B C H I B, C D G H C, D E F G D, be computed according to the method of measuring a trapezoid; then the sum of the contents will be the area of the whole space, A E F H K A, provided that the lines, K I, I H, H G, G F, be straight, and very nearly equal to the true area, when the figure is bounded on one side by a curve; being in excess when K I H G F is concave, and in defect when convex: then will

$$\frac{a + b}{2} \times m = \text{A B I K A},$$

$$\frac{b + c}{2} \times m = \text{B C H I B},$$

$$\frac{c + d}{2} \times m = \text{C D G H C},$$

and $\frac{d + e}{2} \times m = \text{D E F G D}.$

The sum of these areas is $\left(\frac{a + e}{2} + b + c + d\right) m$; that is, if the half sum of the extreme ordinates be added to the intermediate ones, and the sum multiplied by the common distance, the product will give the area: and it is evident that this will always be the case, whatever be the number of ordinates.

Therefore, let a, b, c, d, &c., to p and q, be any series of ordinates whatever, whereof a is the first term, and p and q the two last; then the area of the curvo-rectilinear space will be generally expressed by $\left(\frac{a + q}{2} + b + c + d, \text{ &c. to } p\right)$ $\times m$; now, let l = the length; then if n be equal to the number of ordinates, $n - 1$ will be the number of spaces, or areas; therefore $\left(\frac{a + q}{2} + b + c + d, \text{ &c. to } p\right)$ $\times m = \frac{\left(\frac{a + q}{2} + b + c + d, \text{ &c. to } p\right)}{n - 1} \times l =$ $\frac{a + q + 2b + 2c + 2d, \text{ &c. to } 2p}{2n - 2}$, and the value of the average method, viz. $\frac{a + b + c + d, \text{ &c. to } p + q}{n}$ $\times m \times (n - 1) = \frac{a + b + c + d, \text{ &c. to } p + q}{n} \times l$; then putting one of these equal to the other, there will result $n \times \frac{a + q}{2} = a + b + c + d$, &c. to $p + q$.

It appears, therefore, that there can be no equality except when the half sum of the extreme ordinates, multiplied by the whole number of terms, is equal to the sum of all the ordinates; which, therefore, must be in arithmetical progression, or amount to such.

The method of averaging will therefore be very uncertain; as the half sum of the two extreme terms, multiplied by the number of ordinates, can be taken in any ratio, with respect to the sum of the ordinates.

The difference between the average method and the true method, would be the very same as the difference between $l \times \frac{a + q}{2 \times (n - 1)}$ and $l \times \frac{a + b + c + d, \text{ &c. to } p + q}{n \times (n - 1)}$; for if from two unequal quantities equal quantities be taken away, their difference will still be the same; and if to two unequal quantities equal quantities be added, the difference between the sums will still be the same.

If equimultiples be taken of unequal quantities, the difference between the products will be the same multiple of the difference; and if any aliquot part, or equisubmultiple, be taken of two unequal quantities, the difference will be equal

to the same submultiple of the former difference; now because the equation $n \times \frac{a+q}{2} = a + b + c + d$, &c., to $p + q$, was obtained by dividing each side of the equation $l \times \frac{a+q+2b+2c+2d, \text{ \&c. to } 2p}{2n-2} = l \times \frac{a+b+c+d, \text{ \&c. to } p+q}{n}$ by l, and multiply each side respectively by n, $n-1$, and then adding, or taking away the common parts; by making the divisor l a multiplier, and the multipliers n, $n-1$, divisors; then multiplying the equation $n \times \frac{a+q}{2} = a + b + c + d$, &c. to $p + q$ by l, and dividing it by n and $n-1$, there will arise $l \times \frac{a+q}{2 \times (n-1)} = l \times \frac{a+b+c+d, \text{ \&c. to } p+q}{n \times (n-1)}$.

Example.—Let $a = 4$, $b = 12$, $c = 16$, $d = 18$, $p = 19$, $q = 18$, and $l = 10$;

then $l \times \frac{a+q}{2(n-1)} = 10 \times \frac{4+18}{2 \times (6-1)} = 22$,

and $l \times \frac{a+b+c+d, \text{ \&c. to } p+q}{n+(n-1)} = 10 \times \frac{4+12+16+18+19+18}{6 \times (6-1)} = 29$; the difference is therefore 7, the same as between $\frac{\left(\frac{a+q}{2}+b+c+d, \text{\&c. to } p+q\right)}{n-1} \times l$, and $\frac{a+b+c+d, \text{ \&c. to } p+q}{n} \times l$.

Mensuration of Artificers' Works. All such works, whether superficial or solid, are computed by the rules proper for the figure of them.

The most common instruments for taking the measures are, a five-feet rod, divided into feet and quarters of a foot; and a rule, either divided into inches, or twelfth parts, and each twelfth part into twelve others; a fractional part beyond this division, measurers seldom, or never, take any account of.

When the dimensions are taken by a rule divided in this manner, the best methods to square the dimensions will then be by duodecimals, by the rule of practice, or by the multiplication of vulgar fractions; but, in the opinion of some, the best method of taking dimensions is with a rule, when each foot is divided into ten parts, and each part into ten other parts, or seconds, because the dimensions may be then squared by the rules of multiplication of decimals, which is by far the shortest and readiest method. Those who contend that duodecimals, or cross multiplication, is the easiest method of squaring dimensions, as well as the most exact, are very much mistaken; for if the dimensions are taken in duodecimals, and reduced to decimals, and then squared, the operation, in this case, will certainly be much longer than if it had been done at once by duodecimals, and sometimes not so exact: but if the dimensions are taken in feet, tenths, &c. the operation will not only be easier and shorter, but in many cases will be much more exact than by duodecimals: the reason is obvious to those who consider that there are many cases in which it will be impossible to express, truly, a decimal scale equal to a duodecimal one; neither will it, in many cases, be possible to express accurately, a duodecimal scale equal to a decimal one; duodecimals have the same property with regard to twelfth parts, as decimals have to tenth parts; therefore, in many cases, duodecimals will sometimes circulate and run on, *ad infinitum*, when reduced from decimals, as decimals will, when reduced from duodecimals; and farther, since duodecimals are expressed by a series of twelfth parts, and decimals by a series of tenth parts, in multiplying each of the parts of the former, the trouble of dividing by twelve will then be unavoidable, and more burdensome to the mind than if the operation had been done by the latter, where there is no such division to be made, but merely to multiply as in common mutiplication, and point off the decimal places in the product.

This last method is always to be preferred, as the most natural, as well as the most easy of the two.

Bricklayers' Work.

The mensuration of brickwork has already been treated of at considerable length under that head, but in order to complete the article, we shall give a few more problems and examples.

Problem I.—*To measure the vacuity of a window.*

Find the area of the outside of the window, and multiply that by the number of half bricks thick, from the face of the sash-frame on the outside, to the face of the wall on the same side; to the area so found, at half a brick thick, add the area of the inside vacuity multiplied by the number of half bricks thick, from the face of the sash-frame on the outside, to the face of the brick-work within the building; also add the area of the vacuity of the recess, the height being taken from the bottom of the sash-frame to the floor, and its width the same as the inside vacuity above; multiply this also by the number of half bricks thick, then the sum of these will be the whole vacuity, or void space in the whole window, at half a brick thick; and if required to be reduced to the standard, divide the area so found by 3, and the area of the contents will be reduced to $1\frac{1}{2}$ brick thick.

Example.—Let the height of the outside vacuity be 8 feet, its breadth 4 feet, and half a brick thick; the height of the inside vacuity 8 feet, and its breadth 4 feet 9 inches, and two bricks thick; the recess is 2 feet 9 inches high, 4 feet 9 inches wide, and half a brick thick; required the area of the whole vacuity, at half a brick thick.

Ft.	In.	
8	0	height of the outside vacuity.
4	0	width of the outside vacuity.
32	0	area of the outside vacuity, half a brick thick.
4	9	width of the inside vacuity.
8	0	height of the inside vacuity.
38	0	
4	0	number of half bricks.
152	0	area of the inside vacuity, half a brick thick.
4	9	width of the inside vacuity.
2	9	height of the recess from the floor to the side of the sash.
9	6	
3	6	9
13	0	9 area at $1\frac{1}{2}$ brick thick.
3	0	0
39	2	3 area of the recess, half a brick thick.
32	0	0
152	0	0
223	2	3 area of the whole vacuity, half a brick thick.

PROBLEM II.—*To measure any angle chimney, standing equally distant each way from the angle of the room.*

Multiply the breadth, A B, by the height of the story, and the product by the number of half bricks contained in the half breadth, A B, and it will give the solidity at half a brick thick, after deducting the vacuity, or opening of the chimney.

PROBLEM III.—*To measure an angle chimney, when the plane of its breast intersects the two sides of the room unequally distant from the angle.*

From the points A and B, where the plane of the breast intersects the sides of the room, draw two lines, A E, E B, parallel to the two sides of the room; then multiply either of the lines, A E or E B, suppose E B, by the height of the room, and multiply that product by the number of half bricks contained in the other line, A E, and deduct the vacuity as before, and the remainder will be the content, at half a brick thick.

PROBLEM IV.—*To measure an angle chimney, when the plane of the breast projects out from each wall, and unequally distant from the angle of the room.*

Draw the two lines, G F and F H, parallel to the two sides of the room, as before; then multiply the breadth, F H, by the height of the story, and the product contained in the half of the other side, F G; from this product deduct F D, multiplied by the height of the story, and by the number of half bricks contained in the half of F C, and also the vacuity of the chimney.

PROBLEM V.—*To find the area of an arched aperture.*

To twice the height at the middle add the height of the jambs; and one-third of the sum multiplied by the breadth of the aperture will give the superficial content, sufficiently near for practice.

Example.—Let the height of the arch be 12 feet, each jamb 10 feet, and the breadth of the aperture 5 feet; what is the superficial content?

Feet.
12
2
24
10
3) 34
$11\frac{1}{3}$
5

$56\frac{2}{3}$ feet, tne answer.

But if greater accuracy be required, add the quotient arising from the division of the cube of the altitude by twice the breadth of the aperture, and the sum will be exceedingly near the truth.

Example.—In the foregoing example, the height of the arch is 2 feet, and the chord of the arch, or twice the breadth of the aperture, is 5 feet; then the cube of 2 is 8; and 8 divided by 10, or twice five, gives .8 of a foot for the quantity to be added to the above.

Now the above $56\frac{2}{3}$ = 56.666, &c.

.8

57.466, the area, exceedingly near [the truth.

PROBLEM VI.—*To find the area of a wall, or of the foundation of a building, placed upon a curved surface, supposing it to be built upon uneven ground.*

Divide the length into any number of even parts (the more the truer) by parallel vertical sections; call the first of these sections *odd*, the next *even*, the next *odd*, and so on alternately; and thus the first and last sections will always be odd. Then add together four times the sum of the odd sections, twice the sum of the even sections, and the two ends: divide the sum by three times the number of parts that the length is divided into; then multiply the quotient by the length of the wall, and the product will be the superficial content.

Example.—Suppose a brick wall, 32 feet long, to be divided into eight equal parts, by seven sections of the following heights, taken in successive order, 5 feet, 6 feet, 6 feet 2 inches, 6 feet 3 inches, 5 feet 5 inches, 4 feet, 3 feet, the one end 3 feet and the other 2 feet 6 inches; required the area of the wall.

Now, 5 feet, 6 feet 2 inches, 5 feet 5 inches, and 3 feet, are the odd ordinates; and 6 feet, 6 feet 3 inches, 4 feet, are the even ordinates; therefore,

Feet.	In.
5	0
6	2
5	5
3	0
19	7
	4

Feet.	In.
6	0
6	3
4	0
16	3
	2
32	6

78 4 = four times the sum of the odd sections.
32 6 = twice the sum of the even sections.
3 0 = the one end.
2 6 = the other end.

3) 116 4

8) 38 9 4

4 10 2
32

155 1 4

The following erroneous method is usually practised by measurers and workmen:—

Add all the heights together, and divide the sum by their number; then the quotient, multiplied by the length, is supposed to give the area.

Let us therefore resume the same example by this method·

Feet.	In.
3	0
5	0
6	0
6	2
6	3
5	5
4	0
3	0
2	6

9) 41 4 the sum of all the heights.

4 7 $1\frac{1}{3}$
32

146 11 $6\frac{1}{3}$ the answer, considerably below the truth.

Where the foundation would consist of several straight lines, forming trapezoids, the best method is to find the content of each trapezoid separately; and then adding all the trapezoids together, their sum will be the area of the whole; but if the figure of the ground on which the building is raised be a curve, the measurer will be grossly deceived as to the true contents of the work, unless he divide the length into equal parts, as already recommended.

The contents in brickwork may be found by multiplying the area by 3, and dividing by the number of half bricks.

The following example is added, in order to show the use of the method of equidistant ordinates.

Example.—Let E F G H be a wall of brickwork, or the back of a house, to be built over a public road, or valley, H L G; the under part of the wall is built from the foundation, H L G, up to the level at I K, three bricks thick, and from I K to the top, E F, parallel to it, two bricks and a half thick, to the height of 15 feet, having five windows in it; the vacuities on the outside of each window are 8 feet by 4 feet, and half a brick thick; the vacuities on the inside are 8 feet by 4 feet 9 inches, two bricks thick; the recess on the inside for the finishing of the backs in each window, one and a half brick thick; the height 2 feet 6 inches, from the top of the floor to the sill of the window; the width is that of the vacuity on the inside of the window, viz., 4 feet 9 inches. There is an arched way underneath for carriages, &c. to pass through, whose opening is 12 feet, and its height from the level of the pavement to the crown or top of the arch 11 feet, and the height, from the pavement to the springing of the arch, 9 feet; the under wall is divided into an even number of equidistant spaces, whose ordinates are respectively as follow:—6 feet, 10 feet, 13 feet, 14 feet, 10 feet, 4 feet 6 inches, and 1 foot; the whole length of the building is 50 feet; required the number of bricks, and the quantity of sand and lime to build the said wall.

Explanation.—The under part of the building being an irregular figure, it is measured according to the method of equidistant ordinates, Problem VI.; the upper part is found as in the foregoing examples. The arched way is measured by Problem V. The contents of the windows are obtained by Problem I. Then deduct all the vacuities at half a brick thick from the area of the whole, found as if it were solid, at half a brick thick, as before: the remainder being divided by 3, will reduce it to the standard thickness of one brick and a half.

Feet.	In.		Feet.
10	0		13
14	0		10
4	6		—
			23
28	6		2
4			—
			46

114 0 four times the sum of the even ordinates.
add 46 twice the sum of the odd ordinates.

3) 160

53 4
50

6) 2666 8 [thick.
444 5 area of the under part of the wall, 3 bricks
6 number of half bricks

2666 8 area of the under part of the wall, ½ a brick thick.

Feet.	In.	
15	0	height of the upper part of the wall.
50	0	length.
		[thick.
750	0	area of the upper part of the wall, 2½ bricks
5	0	number of half bricks.
3750	0	area of ditto, ½ a brick thick.
8	0	
4	0	
		[thick.
32	0	area of the vacuity on the outside, ½ a brick
5	0	number of windows.
160	0	area of the vacuities on the outside of five windows, ½ a brick thick.
8	4	
4	9	
33	4	
6	3	
		[window, 2 bricks thick.
39	7	area of the vacuity of the inside for one
5		number of windows.
		[inside.
197	11	area of the vacuities for five windows on the
4		half bricks thick.
791	8	area of the vacuities on the inside, ½ a brick thick.
4	9	
2	6	
9	6	
2	4	6
		[each window 1½ brick thick.
11	10	6 area of the vacuity of the recess under
5		
		[backs, 1½ brick thick.
59	4	6 area of the vacuities of the five window
3		number of half bricks.
178	1	6 area of the vacuities of the five window backs, ½ a brick thick.
11	0	height of the archway, from the pavement to
2		the crown.
22	0	
add 9	0	height from the pavement to the springing of the arch.
31	0	
10	0	width of the archway.
3) 310	0	
		[thick.
103	4	area of the vacuity of the archway, 3 bricks
6		number of ½ bricks thick.
620	0	area of the vacuity of the archway, ½ a brick thick.
160	0	
791	8	
178	1	
620	0	
1749	9	areas of all the vacuities, ½ a brick thick.

Feet.	Inches.	
2666	8	
3750	0	
6416	8	area of the whole ½ a brick thick, as if solid.
deduct 1749	9	
3) 4666	11	true area of the whole, ½ a brick thick.
272) 1555	7	(5 rods 195 feet, reduced to the standard
1360		thickness.
195		

Thus $5.195 \times 4500 = 25726$ number of bricks nearly.
$5.195 \times 1\frac{1}{4} = 7\frac{211}{272}$ cwt. of lime nearly.
$5.195 \times 2\frac{1}{2} = 14\frac{79}{272}$ loads of sand nearly.

To persons, to whom the saving of time is an object, the following tables will be found of great utility in the calculation of brickwork, as well as in the examination of the several operations wrought without them. The explanations and examples of their use will follow.

Table I.

Showing the number of rods contained on the superficies or face of the wall or building, from half a brick to five bricks in thickness, and reduced to the standard measure of one brick and a half thick, being already cast up.

The no. of rods contained upon the surface of the wall.	½ brick.	1 brick.	1½ brick.	2 bricks.	2½ bricks.	3 bricks.	3½ bricks.	4 bricks.	4½ bricks.	5 bricks.
	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.	rd. qr. ft.
1 qr.	0 0 22	0 0 45	0 1 0	0 1 22	0 1 45	0 2 0	0 2 22	0 2 45	0 3 0	0 3 22
2 qr.	0 0 45	0 1 22	0 2 0	0 2 45	0 3 22	1 0 0	1 0 45	1 1 22	1 2 0	1 2 45
3 qr.	0 1 0	0 2 0	0 3 0	1 0 0	1 1 0	1 2 0	1 3 0	2 0 0	2 1 0	2 2 0
1	0 1 22	0 2 45	1 0 0	1 0 22	1 2 45	2 0 0	2 1 22	2 2 45	3 0 0	3 1 22
2	0 2 45	1 1 22	2 0 0	2 2 45	3 1 22	4 0 0	4 2 45	5 1 22	6 0 0	6 2 45
3	1 0 0	2 0 0	3 0 0	4 0 0	5 0 0	6 0 0	7 0 0	8 0 0	9 0 0	10 0 0
4	1 1 22	2 2 45	4 0 0	5 1 22	6 2 45	8 0 0	9 1 22	10 2 45	12 0 0	13 1 22
5	1 2 45	3 1 22	5 0 0	6 2 45	8 1 22	10 0 0	11 2 45	12 1 22	15 0 0	16 2 45
6	2 0 0	4 0 0	6 0 0	8 0 0	10 0 0	12 0 0	14 0 0	16 0 0	18 0 0	20 0 0
7	2 1 22	4 2 45	7 0 0	9 1 22	11 2 45	14 0 0	16 1 22	18 2 45	21 0 0	23 1 22
8	2 2 45	5 1 22	8 0 0	10 2 45	13 1 22	16 0 0	18 2 45	21 1 22	24 0 0	26 2 45
9	3 0 0	6 0 0	9 0 0	12 0 0	15 0 0	18 0 0	21 0 0	24 0 0	27 0 0	30 0 0
10	3 1 22	6 2 45	10 0 0	13 1 22	16 2 45	20 0 0	23 1 22	26 2 45	30 0 0	33 1 22
11	3 2 45	7 1 22	11 0 0	14 2 45	18 1 22	22 0 0	25 2 45	29 1 22	33 0 0	36 2 45
12	4 0 0	8 0 0	12 0 0	16 0 0	20 0 0	24 0 0	28 0 0	32 0 0	36 0 0	40 0 0
13	4 1 22	8 2 45	13 0 0	17 1 22	21 2 45	26 0 0	30 1 22	34 2 45	39 0 0	43 1 22
14	4 2 45	9 1 22	14 0 0	18 2 45	23 1 22	28 0 0	32 2 45	37 1 22	42 0 0	46 2 45
15	5 0 0	10 0 0	15 0 0	20 0 0	25 0 0	30 0 0	35 0 0	40 0 0	45 0 0	50 0 0
16	5 1 22	10 2 45	16 0 0	21 1 22	26 2 45	32 0 0	37 1 22	42 2 45	48 0 0	53 1 22
17	5 2 45	11 1 22	17 0 0	22 2 45	28 1 22	34 0 0	39 2 45	45 1 22	51 0 0	56 2 45
18	6 0 0	12 0 0	18 0 0	24 0 0	30 0 0	36 0 0	42 0 0	48 0 0	54 0 0	60 0 0
19	6 1 22	12 2 45	19 0 0	25 1 22	31 2 45	38 0 0	44 1 22	50 2 45	57 0 0	63 1 22
20	6 2 45	13 1 22	20 0 0	27 2 45	33 1 22	40 0 0	46 2 45	53 1 22	60 0 0	66 2 45
21	7 0 0	14 0 0	21 0 0	28 0 0	35 0 0	42 0 0	49 0 0	56 0 0	63 0 0	70 0 0

Table II.

Showing how many bricks are sufficient to build a piece of brickwork containing any number of feet superficial, from 1 to 90,000; and from half a brick to two bricks and a half; and thence, by addition only, to any thickness or number required, at the rate of 4,500 bricks to the rod, and at the statute thickness of one brick and a half, waste included.

Area of the face of wall.	The number of bricks thick, and quantity required.					Area of the face of wall.	The number of bricks thick, and quantity required.				
	½ brick.	1 brick.	1½ brick.	2 bricks.	2½ bricks.		½ brick.	1 brick.	1½ brick.	2 bricks.	2½ bricks.
1	5	11	16	22	27	600	3308	6617	9926	13235	16544
2	11	22	33	44	55	700	3860	7720	11580	15441	19301
3	16	33	49	66	82	800	4411	8823	13235	17647	22058
4	22	44	66	88	110	900	4963	9926	14889	19852	24816
5	27	55	82	110	137	1000	5514	11029	16544	22058	27573
6	33	66	99	132	165	2000	11029	22058	33088	44117	55147
7	38	77	115	154	193	3000	16544	33088	49632	66176	82720
8	44	88	132	176	220	4000	22058	44117	66176	88235	110294
9	49	99	148	198	248	5000	27573	55147	82720	110294	137867
10	55	110	165	220	275	6000	33088	66176	99264	132352	165441
20	110	220	330	441	551	7000	38602	77205	115808	154411	193014
30	165	330	496	661	827	8000	44117	88235	132352	176470	220588
40	220	441	661	882	1102	9000	49632	99264	148896	198529	248161
50	275	551	827	1102	1378	10000	55147	110294	165441	220588	275735
60	330	661	992	1323	1654	20000	110294	220588	330882	441176	551470
70	386	772	1158	1544	1930	30000	165441	330882	496323	661764	827205
80	441	882	1323	1764	2205	40000	220588	441176	661764	882352	1102940
90	496	992	1488	1985	2481	50000	275735	551470	827205	1102940	1378675
100	551	1102	1654	2205	2757	60000	330882	661764	992646	1323528	1654410
200	1102	2205	3308	4411	5514	70000	386029	772058	1158087	1544116	1930145
300	1654	3308	4963	6617	8272	80000	441176	882352	1323528	1764704	2205880
400	2205	4411	6617	8823	11029	90000	496323	992646	1488969	1985292	2481615
500	2757	5514	72	11029	13786						

TABLE III.

Showing the number of rods contained in any number of feet superficial, from 1 to 10,000; and from ½ a brick to 2½ bricks, and thence, by addition, to any number and to any thickness required, at the rate of 4,500 bricks to the rod.

Feet Super.	½ brick.	1 brick.	1½ brick.	2 bricks.	2½ bricks.
	r. q. ft. in.	r. q. ft. in.	r. q. ft. in.	r. q. ft. in.	r. q. ft. in.
1	0 0 0 4	0 0 0 8	0 0 1 0	0 0 1 4	0 0 1 8
2	0 0 0 8	0 0 1 4	0 0 2 0	0 0 2 8	0 0 3 4
3	0 0 1 0	0 0 2 0	0 0 3 0	0 0 4 0	0 0 5 0
4	0 0 1 4	0 0 2 8	0 0 4 0	0 0 5 4	0 0 6 8
5	0 0 1 8	0 0 3 4	0 0 5 0	0 0 6 8	0 0 8 4
6	0 0 2 0	0 0 4 0	0 0 6 0	0 0 8 0	0 0 10 0
7	0 0 2 4	0 0 4 8	0 0 7 0	0 0 9 4	0 0 11 8
8	0 0 2 8	0 0 5 4	0 0 8 0	0 0 10 8	0 0 13 4
9	0 0 3 0	0 0 6 0	0 0 9 0	0 0 12 0	0 0 15 0
10	0 0 3 4	0 0 6 8	0 0 10 0	0 0 13 4	0 0 16 8
11	0 0 3 8	0 0 7 4	0 0 11 0	0 0 14 8	0 0 18 4
12	0 0 4 0	0 0 8 0	0 0 12 0	0 0 16 0	0 0 20 0
13	0 0 4 4	0 0 8 8	0 0 13 0	0 0 17 4	0 0 21 8
14	0 0 4 8	0 0 9 4	0 0 14 0	0 0 18 8	0 0 23 4
15	0 0 5 0	0 0 10 0	0 0 15 0	0 0 20 0	0 0 25 0
16	0 0 5 4	0 0 10 8	0 0 16 0	0 0 21 4	0 0 26 8
17	0 0 5 8	0 0 11 4	0 0 17 0	0 0 22 8	0 0 28 4
18	0 0 6 0	0 0 12 0	0 0 18 0	0 0 24 0	0 0 30 0
19	0 0 6 4	0 0 12 8	0 0 19 0	0 0 25 4	0 0 31 8
20	0 0 6 8	0 0 13 4	0 0 20 0	0 0 26 8	0 0 33 4
21	0 0 7 0	0 0 14 0	0 0 21 0	0 0 28 0	0 0 35 0
22	0 0 7 4	0 0 14 8	0 0 22 0	0 0 29 4	0 0 36 8
23	0 0 7 8	0 0 15 4	0 0 23 0	0 0 30 8	0 0 38 4
24	0 0 8 0	0 0 16 0	0 0 24 0	0 0 32 0	0 0 40 0
25	0 0 8 4	0 0 16 8	0 0 25 0	0 0 33 4	0 0 41 8
26	0 0 8 8	0 0 17 4	0 0 26 0	0 0 34 8	0 0 43 0
27	0 0 9 0	0 0 18 0	0 0 27 0	0 0 36 0	0 0 45 4
28	0 0 9 4	0 0 18 8	0 0 28 0	0 0 37 4	0 0 46 8
29	0 0 9 8	0 0 19 4	0 0 29 0	0 0 38 8	0 0 48 4
30	0 0 10 0	0 0 20 0	0 0 30 0	0 0 40 0	0 0 50 0
31	0 0 10 4	0 0 20 8	0 0 31 0	0 0 41 4	0 0 51 8
32	0 0 10 8	0 0 21 4	0 0 32 0	0 0 42 8	0 0 53 4
33	0 0 11 0	0 0 22 0	0 0 33 0	0 0 44 0	0 0 55 0
34	0 0 11 4	0 0 22 8	0 0 34 0	0 0 45 4	0 0 56 8
35	0 0 11 8	0 0 23 4	0 0 35 0	0 0 46 8	0 0 58 4
36	0 0 12 0	0 0 24 0	0 0 36 0	0 0 48 0	0 0 60 0
37	0 0 12 4	0 0 24 8	0 0 37 0	0 0 49 4	0 0 61 8
38	0 0 12 8	0 0 25 4	0 0 38 0	0 0 50 8	0 0 63 4
39	0 0 13 0	0 0 26 0	0 0 39 0	0 0 52 0	0 0 65 0
40	0 0 13 4	0 0 26 8	0 0 40 0	0 0 53 4	0 0 66 8
41	0 0 13 8	0 0 27 4	0 0 41 0	0 0 54 8	0 1 0 4
42	0 0 14 0	0 0 28 0	0 0 42 0	0 0 56 0	0 1 2 0
43	0 0 14 4	0 0 28 8	0 0 43 0	0 0 57 4	0 1 3 8
44	0 0 14 8	0 0 29 4	0 0 44 0	0 0 58 8	0 1 5 4
45	0 0 15 0	0 0 30 0	0 0 45 0	0 0 60 0	0 1 7 0
46	0 0 15 4	0 0 30 8	0 0 46 0	0 0 61 4	0 1 8 8
47	0 0 15 8	0 0 31 4	0 0 47 0	0 0 62 8	0 1 10 4
48	0 0 16 0	0 0 32 0	0 0 48 0	0 0 64 0	0 1 12 0
49	0 0 16 4	0 0 32 8	0 0 49 0	0 0 65 4	0 1 13 8
50	0 0 16 8	0 0 33 4	0 0 50 0	0 0 66 8	0 1 15 4
60	0 0 20 0	0 0 40 0	0 0 60 0	0 1 12 0	0 1 32 0
70	0 0 23 4	0 0 46 8	0 1 2 0	0 1 25 4	0 1 48 8
80	0 0 26 8	0 0 53 4	0 1 12 0	0 1 38 8	0 1 65 4
90	0 0 30 0	0 0 60 0	0 1 22 0	0 1 52 0	0 2 14 0
100	0 0 33 4	0 0 66 8	0 1 32 0	0 1 65 4	0 2 30 8
200	0 0 66 8	0 1 65 4	0 2 64 0	0 3 62 8	1 0 61 4
300	0 1 32 0	0 2 64 0	1 0 28 0	1 1 60 0	1 3 24 0
400	0 1 65 4	0 3 62 8	1 1 60 0	1 3 57 4	2 1 54 8
500	0 2 30 8	1 0 61 4	1 3 24 0	2 1 54 8	3 0 17 4
600	0 2 64 0	1 1 60 0	2 0 56 0	2 3 52 0	3 2 48 0
700	0 3 29 4	1 2 58 8	2 2 20 0	3 1 49 4	4 1 10 8
800	0 3 62 8	1 3 57 4	2 3 52 0	3 3 46 8	4 3 41 4
900	1 0 28 0	2 0 56 0	3 1 16 0	4 1 44 0	5 2 4 0
1000	1 0 61 4	2 1 54 8	3 2 48 0	4 3 41 4	6 0 34 8
2000	2 1 54 8	4 3 41 4	7 1 28 0	9 3 14 8	12 1 1 4
3000	3 2 48 0	7 1 28 0	11 0 8 0	14 2 56 0	18 1 36 0
4000	4 3 41 4	9 3 14 8	14 2 56 0	19 2 29 4	24 2 2 8
5000	6 0 34 8	12 1 1 4	18 1 36 0	24 2 2 8	30 2 37 4
6000	7 1 28 0	14 2 56 0	22 0 16 0	29 1 44 0	36 3 4 0
7000	8 2 21 4	17 0 42 8	25 2 64 0	34 1 17 4	42 3 38 8
8000	9 3 14 8	19 2 29 4	29 1 44 0	39 0 58 8	49 0 5 4
9000	11 0 8 0	22 0 16 0	33 0 24 0	44 0 32 0	55 0 40 0
10000	12 1 1 4	24 2 2 8	36 3 4 0	49 0 5 4	61 1 6 8

TABLE IV.

Showing the value of reduced brickwork per rod, calculated at the several prices of £3 5s.—£3 10s.—£3 15s.—£4.—£4 5s.—and £4 10s. per rod, for mortar, labour, and scaffolding, and of bricks, from £1 10s. to £3 per thousand; allowing 4,500 bricks to a rod.

Bricks, per thousand.	Mortar and labour, £3 5s. per rod.	Mortar and labour, £3 10s. per rod.	Mortar and labour, £3 15s. per rod.
£. s. d.	£. s. d.	£. s. d.	£. s. d.
1 10 0	10 0 0	10 5 0	10 10 0
1 12 0	10 9 0	10 14 0	10 19 0
1 14 0	10 18 0	11 3 0	11 8 0
1 16 0	11 7 0	11 12 0	11 17 0
1 18 0	11 16 0	12 1 0	12 6 0
2 0 0	12 5 0	12 10 0	12 15 0
2 2 0	12 14 0	12 19 0	13 4 0
2 4 0	13 3 0	13 8 0	13 13 0
2 6 0	13 12 0	13 17 0	14 2 0
2 8 0	14 1 0	14 6 0	14 11 0
2 10 0	14 10 0	14 15 0	15 0 0
2 12 0	14 19 0	15 4 0	15 9 0
2 14 0	15 8 0	15 13 0	15 18 0
2 16 0	15 17 0	16 2 0	16 7 0
2 18 0	16 6 0	16 11 0	16 16 0
3 0 0	16 15 0	17 0 0	17 5 0

Bricks, per thousand.	Mortar and labour, £4 0s. per rod.	Mortar and labour, £4 5s. per rod.	Mortar and labour, £4 10s. per rod.
£. s. d.	£. s. d.	£. s. d.	£. s. d.
1 10 0	10 15 0	11 0 0	11 5 0
1 12 0	11 4 0	11 9 0	11 14 0
1 14 0	11 13 0	11 18 0	12 3 0
1 16 0	12 2 0	12 7 0	12 12 0
1 18 0	12 11 0	12 16 0	13 1 0
2 0 0	13 0 0	13 5 0	13 10 0
2 2 0	13 9 0	13 14 0	13 19 0
2 4 0	13 18 0	14 3 0	14 8 0
2 6 0	14 7 0	14 12 0	14 17 0
2 8 0	14 16 0	15 1 0	15 6 0
2 10 0	15 5 0	15 10 0	15 15 0
2 12 0	15 14 0	15 19 0	16 4 0
2 14 0	16 3 0	16 8 0	16 13 0
2 16 0	16 12 0	16 17 0	17 2 0
2 18 0	17 1 0	17 6 0	17 11 0
3 0 0	17 10 0	17 15 0	18 0 0

TABLE V.—Showing the value of brickwork reduced to one brick and a half thick, from 5s. 8d. per rod, to £20 per rod and from a farthing to 1s. 6d. per foot.

Per foot.	Per rod.	Per foot.	Per rod.	Per foot.	Per rod.
	£. s. d.				
0d.		6d.	6 16 0	12d.	13 12 0
¼	0 5 8	¼	7 1 8	¼	13 17 8
½	0 11 4	½	7 7 4	½	14 3 4
¾	0 17 0	¾	7 13 0	¾	14 9 0
1d.	1 2 8	7d.	7 18 8	13d.	14 14 8
¼	1 8 4	¼	8 4 4	¼	15 0 4
½	1 14 0	½	8 10 0	½	15 6 0
¾	1 19 8	¾	8 15 8	¾	15 11 8
2d.	2 5 4	8d.	9 1 8	14d.	15 17 4
¼	2 11 0	¼	9 7 0	¼	16 3 0
½	2 16 8	½	9 12 8	½	16 8 8
¾	3 2 4	¾	9 18 4	¾	16 14 4
3d.	3 8 0	9d.	10 4 0	15d.	17 0 0
¼	3 13 8	¼	10 9 8	¼	17 5 8
½	3 19 4	½	10 15 4	½	17 11 4
¾	4 5 0	¾	11 1 0	¾	17 17 0
4d.	4 10 8	10d.	11 6 8	16d.	18 2 8
¼	4 16 4	¼	11 12 4	¼	18 8 4
½	5 2 0	½	11 18 0	½	18 14 0
¾	5 7 8	¾	12 3 8	¾	18 19 8
5d.	5 13 4	11d.	12 9 4	17d.	19 5 4
¼	5 19 0	¼	12 15 0	¼	19 11 0
½	6 4 8	½	13 0 8	½	19 16 8
¾	6 10 4	¾	13 6 3	¾	20 2 4

TABLE VI.

Showing what number of plain tiles, or pan-tiles, will cover any area from 1 to 10,000 feet.

Feet Super.	Plain tiles. Gauges. 6 inch.	6½ inch.	7 inch.	Pan-tiles. Gauges. 11 inch.	12 inch.	13 inch.
1	7½	7	6½	1⅔	1½	1⅓
2	15	14	13	3⅓	3	2⅔
3	22½	21	19½	5	4½	4
4	30	28	26	6⅔	6	5⅓
5	37½	35	32½	8⅓	7½	6⅔
6	45	42	39	10	9	8
7	52½	49	45½	11⅔	10½	9⅓
8	60	56	52	13⅓	12	10⅔
9	67½	63	58½	15	13½	12
10	75	70	65	16⅔	15	13⅓
20	150	140	130	33⅓	30	26⅔
30	225	210	195	50	45	40
40	300	280	260	66⅔	60	53⅓
50	375	350	325	83⅓	75	66⅔
60	450	420	390	100	90	80
70	525	490	455	116⅔	105	93⅓
80	600	560	520	133⅓	120	106⅔
90	675	630	585	150	135	120
100	750	700	650	166⅔	150	133⅓
200	1500	1400	1300	333⅓	300	266⅔
300	2250	2100	1950	500	450	400
400	3000	2800	2600	666⅔	600	533⅓
500	3750	3500	3250	833⅓	750	666⅔
600	4500	4200	3900	1000	900	800
700	5250	4900	4550	1166⅔	1050	933⅓
800	6000	5600	5200	1333⅓	1200	1066⅔
900	6750	6300	5850	1500	1350	1200
1000	7500	7000	6500	1666⅔	1500	1333⅓
2000	15000	14000	13000	3333⅓	3000	2666⅔
3000	22500	21000	19500	5000	4500	4000
4000	30000	28000	26000	6666⅔	6000	5333⅓
5000	37500	35000	32500	8333⅓	7500	6666⅔
6000	45000	42000	39000	10000	9000	8000
7000	52500	49000	45500	11666⅔	10500	9333⅓
8000	60000	56000	52000	13333⅓	12000	10666⅔
9000	67500	63000	58500	15000	13500	12000
10000	75000	70000	65000	16666⅔	15000	13333⅓

A general Explanation of the Tables and their Construction.

In Tables, which may be calculated by a proportion, in which one of the terms is constantly the same, and consequently the other two only variable, the given data, or numbers, are always of two kinds; one of the kinds is placed in one row, and the other in another row, at a right angle therewith; the former being parallel to the edges of the page, and upon the left hand, and the other perpendicular to the said edges, and at the top of the page: we shall call the former, the given vertical column; and the latter, the given horizontal row; the first part of the given horizontal row over the given vertical column, contains the title of this column; and the given numbers of this horizontal row follow each other in succession, having each a separate cell with the title at the top; then other rows are made in a line with each cell, parallel to the given vertical column, so that the respective numbers which form the said columns may also line with the numbers in the left-hand vertical column: then each of these numbers, so disposed, are to be the answers of the two numbers at the extremity of the legs in each given row. From this it appears, that the answer is in the concourse of the given column and row, traced from each given datum parallel to the given columns in which the data are inserted. All the useful variations of one of the given species, or kinds, are expressed by one or several arithmetical progressions, in the given vertical column, and the other species in an arithmetical progression in the given horizontal row. If the given vertical column consist only of one arithmetical progression, the answer for any number in the said column, between the first and the last, may be obtained at once: but if the given vertical column consist of several arithmetical progressions, *viz.* from 1 to 10, from 10 to 100, from 100 to 1000, &c., the common difference of the following progression being 10 times greater than that which precedes it, then the given number belonging to the vertical column must be divided into component parts, so as to correspond with as many of the numbers to be found in the progressions; each of the answers are to be taken out separately, and added together, and the sum will be the answer in full. Where the given vertical column consists of one or more arithmetical progressions, so will each vertical column of answers consist of as many arithmetical progressions, and each horizontal row of answers will also form an arithmetical progression; therefore in the construction of the Table, there is no necessity for calculating by the rule of proportion, nor even by plain division or multiplication, except in the first or uppermost two numbers in the first and second vertical columns of answers; the difference of each of these numbers, so found, is the common difference of the progression in the first horizontal row of answers; then this common difference being added to that at the head of the second column gives the next towards the right hand, or the uppermost answer at the head of the third vertical column; the common difference being added to this sum, again gives the next succeeding answer, and so on to the end of the horizontal progression: proceed with each vertical column by adding the common difference in the same way throughout each progression, if more than one; observing, that whatever number of times the common difference of any following progression in the given vertical column contains the common difference in the preceding progression, so must the common difference of any following corresponding progression, in any vertical column of answers, contain the common difference of the arithmetical progression immediately preceding in the same column.

One thing may be observed in each vertical column, where the answers consist of integers only, and where there are several arithmetical progressions, from 1 to 10, from 10 to 100, from 100 to 1000, and where each progression is formed of 10 terms, all the numbers of the first progression are to be found respectively in as many of the first figures of the second progression, and all the figures of each number in the second progression are to be respectively found in as many of the first figures of each of the numbers in the third progression, and so on, whatever be the number of progressions: therefore, if the last progression be constructed, the whole of the progressions upwards may also be constructed: for whatever number of figures each number of the lower progression consists of, each number of the progression immediately above will respectively consist of the same, wanting the right-hand figure; likewise the third progression will have the same number of figures in each number, wanting one, that each respective number has in the second progression, or wanting two that each respective number in the undermost progression has. So that, by proper attention, one small Table, consisting only of 10 horizontal rows, will give the answer for any number whatever.

In Tables where the given columns consist of different denominations, the answers may be first obtained in one denomination, and afterwards each of the answers may be divided into the several denominations it will resolve into, in order to facilitate the construction of the Tables.

TABLE I.

Explanation.—At the head of this table, over each vertical column, is the thickness of the wall in bricks and half bricks, *viz.* from ½ a brick to 5 bricks; the first vertical column, or that on the left hand, contains the number of rods, from ¼ to 21, and each succeeding column towards the right shows the number of rods, quarters, and feet, reduced to a brick and a half, according to the thickness expressed at the top of the column, and to the number of rods to be found in the same horizontal line in the first column.

Use.—Suppose a wall, 2½ bricks thick, contained 8 rods, how many standard rods does the wall contain? Look for 8 rods in the first column, carry your eye horizontally to the 2½ brick column, in which you will find 13 1 22; that is, 13 rods, 1 quarter, and 22 feet; and so proceed for any other quantity and thickness.

Construction of the Table.—Multiply the number of superficial rods expressed in any number of the first column, by the number of half bricks that the wall is in thickness, divide the product by 3, and the quotient will exhibit the number of reduced rods: multiply the remainder, if any, by 272, and ⅓ of the product will be reduced feet; the inches not being noticed. Now, as 68 feet are the quarter of a rod, the quotient, if it equal or exceeds 68, must be divided thereby, and the last quotient will give the quarters of a rod, and the remainder, if any, will be feet.

Example.—Let it be required to find to the quantity of reduced work in a wall 2½ bricks thick, the superficial measure being 8 rods:

8
5 half bricks
3) 40
13 90

Then 68) 90 (1
68
22

	Rds.	Ft.	R.	Qt.	Ft.
That is	13	90 =	13	1	22

And thus for any other number of superficial rods. A Table, similar to the above, may be found in Leadbeater's *Gentleman's and Tradesman's Assistant*, second edition; and also in Crosby's *Builder's Price Book.*

TABLE II.

Explanation and Use.—The first column contains the number of superficial feet, from 1 to 10 inclusive, the common difference being 1; from 10 to 100 inclusive, the common difference being 10; from 100 to 1000 inclusive, the common difference being 100; from 1000 to 10,000 inclusive, the common difference being 1000; and from 10,000 to 90,000 inclusive, the common difference being 10,000. The adjacent vertical columns, towards the right, show the number of bricks respectively required to build a wall at the thickness of ½, 1, 1½, 2, 2½ bricks, according to the superficial feet expressed by the number in the first vertical column, in the same horizontal line.

Let it be required to find the number of bricks necessary to build a wall half a brick thick, containing an area of 4850 feet: Divide the number into its component parts thus, 4850 = 4000 + 800 + 50, then look for each of these parts separately, and you will find, that

4000	will require	22058	} add these together,
800	„ „	4411	
50	„ „	275	
and the whole 4850	„ „	26744	

Again, let it be required to find the number of bricks that will build a wall two bricks thick, containing an area of 35,864 feet: then say, 35,864 = 30 000 + 5,000 + 800 + 60 + 4, and you will find that—

30000	will require	661764
5000	„ „	110294
800	„ „	17647
60	„ „	1323
4	„ „	88
35864	„ „	791116

Construction.—Reduce the standard rod of 272 feet, and the given area, into walls of half a brick thick; then say, as the number of feet in the standard, thus reduced, is to the area reduced to the same thickness, so is 4,500 bricks, the quantity required to build the former, to the quantity required to build the latter.

Example I.—How many bricks will be required to build a wall containing an area of 35,864 feet, two bricks thick?

Then 272 : 35864 :: 4500
3 4
816 143456
4500
71728000
573824

816) 645552000 (791117 the answer.
5712
7435
7344
912
816
960
816
1440
816
6240
5712
528

The answer is within one of what is obtained from the Tables; the difference arises from the fractions being lost, in adding the several parts together.

Example II.—How many bricks will be required to build a partition wall, half a brick thick, containing an area of 4850 feet?

272 : 4850 :: 4500
3 1
Then 816 4850
4500
2425000
19400

816) 21825000 (26746 the number required, which is rather more than the aggregate found by the Tables, the remainders being omitted in adding the component parts together.
1632
5505
4896
6090
5712
3780
3264
5160
4896
264

In this manner, by the rule of proportion, every number in the Table may be found. Or if the solidity of the wall be divided by the solidity of a brick, both of the same dimension, the quotient will give the number of bricks; but this operation will not be shorter than the above.

In Salmon's *Architect's Assistant*, is a Table similar to that above described, showing the number of bricks necessary to build a wall, from half a brick to two bricks and a half thick inclusive, and from one foot on the surface, to 27,000 inclusive. The column of feet goes on from unity to 100 inclusive, the common difference being one; then from 100 to 1,000 inclusive, the common difference being 100; and lastly from 1,000 to 27,000 inclusive, the common difference being 1,000.

But there is no advantage in a long table, unless the number could be found at once without addition, which is not generally the case. The short Table here introduced, is extended farther than Salmon's, and is much more handy.

Another Table, of the same description, was published by Mr. J. Leadbeater, and assistants, in his *Gentleman's and Tradesman's Complete Assistant*. The progression of the numbers expressing the area is exactly the same as in Salmon's, except that the latter author's work contains two horizontal lines more than the former; the one ending in 27,000, the other in 25,000; and with the exception of the following numbers, all the others correspond:

In the one-brick column, opposite 35, Salmon has 381, and Leadbeater 386, the difference is 5, but Leadbeater is right.

In the same column, opposite 45, Salmon has 502, and Leadbeater 503: but the number ought to be 496.

In the brick-and-half column, opposite 53, Salmon has 876, and Leadbeater 878; the true number is 876, or more nearly 877: in this instance they differ but little from the truth.

In the one-brick column, opposite 62, Salmon has 689, and Leadbeater 696; which are both in excess; the true number being 683, or very nearly 684. The greatest difference is 12 or 13 that Leadbeater is beyond the truth.

In the brick-and-half column, opposite 84, Salmon has 1389, and Leadbeater 1380; which are both in excess; the true number being 1356. Salmon, who has the greatest, exceeds the truth by 33.

In the same column, opposite 97, Salmon has 1604, and Leadbeater 1614: Salmon is right.

And lastly, in the two-and-a-half brick column, opposite 12,000, Salmon has 343,087, and Leadbeater 353,087, which are both vastly beyond the truth, which is 330,882. Salmon is therefore 12,205 in excess, and Leadbeater 22,205.

These differences are so great, and the nearest so wide of the truth, that one must suppose, either that these gentlemen were governed by no regular rule, or that they were very careless; for indeed they might have come nearer to the required number at a mere guess.

But if in the few numbers here examined, such enormous differences appear, what may not be expected from the far greater part of them?

It may perhaps happen that these differences, as they are few, are typographical errors; and should this be the case, it is most probable that one has copied from the other. The quotations from these works are from the second edition; Salmon's is dated 1748, and Leadbeater's 1769.

In Crosby's *Builder's Price Book*, by Phillips, for 1811, is a similar Table; and I am sorry to find, in a book of so much reputation, that the same numbers are to be found as in Salmon's and Leadbeater's, except in the four following:

In the one-brick column, opposite 20, Crosby has 223, and Salmon and Leadbeater, each, 220, the true number.

In the two-brick column, opposite 300, Crosby has 6626, and Salmon and Leadbeater, 6616, the true number.

In the two-and-a-half brick column, first, opposite 50, Crosby has 1476, and Salmon and Leadbeater, 1478; but the true number is 1378: Secondly, opposite 5000, Crosby has 145,953, and Salmon and Leadbeater, 142,953; whereas the true number is 137,867.

These numbers are so nearly alike in the three books here mentioned, that the differences appear to be no more than typographical errors; whence we may conclude that Leadbeater's *Assistant* has been copied from Salmon's, and the Table in Crosby's from one of them; for though it is much contracted, the errors in the numbers are the same.

If compilers in general would be at the necessary pains of examining what they intend to adopt, three-fourths of the books that are published on scientific subjects would never have appeared; the far greater part of them are made from scraps of others, and many are exactly the same in substance, only slightly varied in the arrangement, or in a single word now and then; and even whole paragraphs or sections are frequently to be met with, and sometimes whole works are copied, without any acknowledgment of the original author. Such is the case with the three authors alluded to; neither of the latter two takes any notice of the first; but taking it for granted that he is right, and depending upon this, they each make the part thus adopted their own, little suspecting that these antiquated works would ever undergo re-examination. But happy it is for scientific subjects, and for original writers, that there are still some few men of principle who will pry to the bottom of the greatest difficulties, and undergo the most laborious calculations; and though such authors as those referred to, may have credit in the mean time for what they have done, they must be ultimately exposed to that censure which their works so justly deserve.

There is hardly a number in the latter part of these Tables but is wrong, in some instances even to thousands: but as I have put the reader in possession of a method by which to examine them, he may do it at his leisure; or he may compare any of the other numbers with those here inserted.

When such errors arising from carelessness, are to be found in a single Table of a Price Book, is there not reason to suppose that in other parts, not examined, they abound equally, and therefore create a doubt as to the degree of dependence to be placed in any one article? There is no man perfect; and when different ideas crowd upon the mind of a writer at the same time, in treating of subjects that have not been before investigated, he may inadvertently insert a wrong word, or a typographical error may escape his notice; but in most cases this will be easily detected, as other parts of the subject will readily ascertain the author's meaning, or otherwise it may be deduced from a palpable contradiction in terms, where only one idea could be meant.

Table III.

Explanation.—The first vertical column contains the contents of the wall in superficial feet, the given row the thickness in bricks and half-bricks, and the other vertical columns the answers.

Use.—What is the quantity of reduced brickwork in a wall containing 5,348 feet superficial and $2\frac{1}{2}$ bricks thick?

Say, 5,348 = 5,000 + 300 + 48: then we have by the Table

			R.	Qr.	Ft.	In.
5000	will	require	30	2	37	4
300	"	"	1	3	24	0
48	"	"	0	1	12	0
consequently 5348	"	"	32	3	5	4

The same found by the rule thus:

```
                5348
                   5
               ------
            3)26740
               ------          R. Qr. Ft. In.
          272)8913 4 (32 3 5 4, the answer, as
              816                    before.
              ---
               753
               544
               ---
             68)209(3
                204
                ---
                  5
```

The rule here applied is the same as Rule I. p. 50, vol I. As the first progression goes on from 1 to 50 inclusive, and two adjacent numbers differing by unity, any number from 50 to 1 may be taken at once.

Example.—In a wall of two bricks thick, containing an area of 47 feet, what is the standard measure?

In the meeting of the 2-brick column and the horizontal row from 47, you have 62 feet 8 inches, the answer required.

In constructing a table, such as this, with different denominations, it will be much more ready to find the whole numbers, as in the last Table, in the least denomination, and afterwards to divide each respective number by as many as will make one of the next denomination; then the quotient is so many of this denomination, and the remainder, if any, so many of the first; and if the quotient exceed the number that makes one of the third denomination, divide it by this number, and the second quotient is so many of the third denomination, and the remainder, if any, so many of the second; and so on, as long as division can be made.

TABLE IV.

Explanation and Use.—As the prices of bricks and of labour may vary in any ratio in respect of each other, it is convenient to have a price at once agreeable to these variations, which can be easily obtained from this Table. The given price of bricks per thousand is arranged in the first vertical column, the price of mortar and labour in the given horizontal row, and the required price per rod is found, as in the other Tables, in the point or place of intersection of the horizontal row and vertical column, carried from each of the given prices.

Example.—What is the price of a rod of brickwork, when the rate of bricks is £1 18s. per thousand, and the price of mortar and labour £3 10s. per rod?

Carry your eye horizontally from £1 18s. in the given column of bricks, until you come to the vertical column under £3 10s. the given price of labour and mortar; and you will find £12 1s. the price of the rod, as required.

Construction.—Multiply the price of bricks per thousand by $4\frac{1}{2}$, and add the product to the price of labour at the top, and you will have the price per rod, as in the Table. Let us take the above as an example: then (£1 18s.) $\times$ $4\frac{1}{2}$ = £8 11s. the price of bricks in a rod, to the product; add £3 10s. the price of labour and mortar, and you will have £12 1s. as before.

This Table might be otherwise constructed, by giving a Table of the variations of lime and sand, but then it would be much longer. The articles of labour, lime, and sand, are classed together, upon the supposition or probability, that the increase or decrease of either of the two is nearly in the same ratio; but should it prove otherwise, and the disparity be great, a Table must be constructed upon different principles.

TABLE V.

Explanation and Use.—This Table consists of only two vertical columns; the price per foot is contained in the first and the price per rod in the second column. So that if the price per foot be given, you have the price per rod in the same horizontal line; or the very reverse is sometimes necessary, when the price per rod is given, to know the price per foot.

Example.—What will 3r. 258ft. of reduced brickwork come to, at £2 16s. 8d. per rod? First multiply £2 16s. 8d. by 3; look for £2 16s. 8d. under the column per rod, on the left hand of it, you have $0\frac{1}{2}$d. for the price per foot; therefore multiply 258 feet by $\frac{1}{2}$, that is, divide it by 2, and you will have the number of pence, which divided by 12 will give the shillings. Thus:

£.	s.	d.	Feet.
2	16	8	2)258
		3	
			12)129
8	10	0	
	10	9	10 9
9	0	9	

To perform such operations entirely by rule is sometimes very tedious.

Construction.—The quantity of superficial feet in a rod is 272; this being multiplied by the price per foot, gives evidently the price per rod: Suppose $0\frac{3}{4}$d. per foot, what is the price per rod?

```
Thus:          272
multiplied by    3
                ---
              4)816
                ---
             12)204 pence per rod.
                ---
              17 shillings.
```

TABLE VI.

Explanation.—The different gauges are contained in the top row, the given areas in the first vertical column, and the answers in the succeeding vertical columns.

Example.—How many tiles are sufficient, at a 7-inch gauge, to cover an area of 5.349 feet?

Here 5349 = 5000 + 300 + 40 + 9.

Now,	5000	will require	32,500
	300	" "	1,950
	40	" "	260
	9	" "	$58\frac{1}{2}$
therefore	5349	" "	$34{,}768\frac{1}{2}$

Or thus, by calculation:—It is evident that the numbers are as the areas: suppose it is ascertained that 52 plain tiles will cover 8 feet superficial, at a 7-inch gauge, we shall then have, as the area of 8 feet, is to the area of 5,349 feet, so is 8 tiles, the number required for 8 feet, to the number of tiles required, $34{,}768\frac{1}{2}$.

```
Thus 8 : 5349 : : 52
           52
          ---
        10698
        26745
        -----
      8)278148
        -----
```

[by the Table.

$34768\frac{1}{2}$ the answer, as above found

It may be observed in this, as all the foregoing Tables, that any two numbers in any vertical column, are in the same ratio as any other two opposite numbers in any other vertical column; that is, as any number in any vertical column is to any other number in the same column, so is any number opposite the former in any other column to the number opposite the latter in this last column.

The following memoranda, extracted principally from an useful little work entitled the Student's Guide to Measuring and Vaulting Artificers' work, may prove useful.

Size and Weight of Various Articles.

	Length.		Breadth.		Thickness.		Weight.	
	Ft.	In.	Ft.	In.	Ft.	In.	lbs.	oz.
Stock bricks..... each	0	8¾	0	4½	0	2½	5	0
Paving " ..... ditto	0	9	0	4½	0	1⅝	4	0
Dutch clinkers..... ditto	0	6½	0	3	0	1½	1	8
12-Inch paving tiles .... ditto	0	11¾	0	11¾	0	1½	13	0
10-Inch " " .... ditto	0	9¾	0	9¾	0	1	8	9
Pan-tiles..... ditto	1	1½	0	9½	0	0½	5	4
Plain tiles ..... ditto	0	10½	0	6½	0	0⅝	2	5
Pan-tile laths, per 10-feet bundle	120	0	0	1½	0	1	4	6
Ditto, per 12-feet bundle	144	0	0	1½	0	1	5	0
(A bundle contains 12 laths.)								
Plain tile laths, per bundle....	500	0	0	1	0	0½	3	0
(Thirty bundles of laths make a load.)								

A bricklayer's hod measures 1 foot, 4 inches, × 9 inches × 9 inches, and contains 20 bricks.

A single load of sand is 27 cubic feet, or 1 cubic yard, and contains 18 heaped or 21 striked bushels, and 23½ cubic feet equal one ton.

A double load of sand is 54 cubic feet, or 2 cubic yards.

A measure of lime is 27 cubic feet, or 1 cubic yard, and contains from 16 to 18 bushels.

Quantities.

A rod of brickwork measures 16 feet, 6 inches × 16 feet, 6 inches, or 272 feet, 3 inches superficial, 1½ brick, or 13½ inches thick, called the standard thickness, or 306 cubic feet, or 11½ cubic yards; and weighs 13 tons.

A rod of brickwork, laid to a 12-inch gauge, *i. e.* four courses to measure 1 foot in height, requires 4353 stock bricks.

Ditto, laid to 11½-inch gauge, requires 4533 stock bricks.

A foot of reduced brickwork requires 16 bricks.

These calculations are made without allowance for waste, and indeed there is very little, as nearly every part is worked in, and much space is occupied by timbers, flues, &c., for which no deduction is made in measurement; and therefore, in the erection of dwelling houses, containing flues and bond timbers, 4300 stocks is quite sufficient, and this is the usual number allowed for a rod of brickwork.

5370 stocks to the rod, if laid dry; 4900 ditto, in wells and circular cess-pools.

A rod of brickwork, laid four courses to gauge 12 inches, contains 235 feet cube of bricks, and 71 feet cube of mortar, and the average weight is about 15 tons.

A rod of brickwork requires 1½ cube of chalk lime, and 3 loads of sand, or 36 bushels of cement and 36 bushels of sharp sand.

A cubic yard, or load of mortar, requires 9 bushels of lime and one load of sand.

The proportion of mortar or cement, when made up to the materials in their unmixed state, is as two to three.

Facing requires 7 bricks per foot superficial.

Gauged arches, 10 ditto ditto.

Brick-nogging, per yard superficial, requires 30 bricks on edge, or 45 laid flat.

Description.			Number required.
Paving.			
Stock bricks, laid flat	per yard		36
Ditto, on edge	—		52
Paving bricks, laid flat	—		36
Ditto, on edge	—		82
Dutch clinkers, ditto	—		140
12-inch paving tiles	—		9
10-inch ditto	—		13
Tiling.	Gauge—Inches.		
Pan-tiles per square	12		150
Ditto ditto	11		164
Ditto ditto	10		180

A square of pan-tiling requires 1 bundle of laths, and 1¼ hundred of 6d. nails.

Plain tiles, per square	4		600
Ditto ditto	3½		700
Ditto ditto	3		800
Ditto ditto	laid flat		210

A square of plain tilling requires one bundle of laths and nails, one peck of tile-pins, and 3 hods of mortar.

The laths are sold in bundles of 3, 4, and 5 feet lengths; a bundle of 3 feet contains 8 score; 4 feet, 6 score; and 5 feet, 5 score. The nails used are fourpenny; and the number required for a bundle of 5 feet and 6 feet laths, are 500 and 600 respectively.

Calculation of Labour.

Digger.—The amount of digging which a man can perform in a day depends so much on the nature of the soil on which he has to operate, that it is almost impossible to fix a Constant for this description of labour. The following data may, however, serve as a slight guide:

In loose ground a man will throw up about 10 cubic yards per day, but in hard or gravelly soil, where hacking is necessary, from 3 to 5 cubic yards, according to the hardness of the ground, will be a fair day's work.

Wheeling is estimated by the run of 20 yards. A gang of 3 men, 2 for filling and 1 for wheeling, will remove about 30 yards per day to this distance; and the labour for removing earth may be calculated according to the distance, allowing 3 men to the first run, and an additional man for every 20 yards of distance. [17½ cubic feet of clay weighs one ton. 18 cubic feet of common earth weighs one ton.]

The following table, though far from complete, contains Constants for all the principal descriptions of bricklayer's work.

Concrete.—Labour in mixing, wheeling, throwing in from a stage, and puddling (when required to be done), including erection of scaffolding, per yard cube	.335
(The Constant to be multiplied by the rate of wages for a labourer per day.)	
Brickwork, per rod	4.941
(To be multiplied by the rate of wages of a bricklayer and labourer per day.)	
Extra labour to malm facings	.014
(To be multiplied by the rate of wages for a bricklayer per day.)	
Paving.	
Brick paving, laid flat in sand, per yard	.046
on edge in sand —	.075
flat in mortar —	.056
edge in mortar —	.084
Paving brick laid flat in sand —	.046
on edge in sand —	.106
laid flat in mortar —	.175
on edge in mortar —	.121
Clinker paving on edge in sand —	.132
10 or 12-inch tile paving —	.010

Tiling.

Pan-tiling, laid dry	per square	.422
pointed outside	—	.685
inside	—	.790
Plain tiling laid to a 4-inch gauge	—	.739
to a 3½-inch gauge	—	.764
to a 3-inch gauge	—	.790

The above Constants all to be multiplied by the rate of wages for a bricklayer and labourer per day.

MASONS' WORK.

Masons' work is measured in the same manner as bricklayers', so far as the superficial content is concerned.

The joints of the plane surface of an ashlar wall are measured in breath, according to the thickness of the ashlar work, which is generally about six inches; and the two surfaces which are supposed to come in contact, or to be cemented, both of the vertical and horizontal joints, are accounted as only one surface, as in cornices; and are supposed to be equivalent to that of the vertical facing of the wall after being rubbed smooth.

In brick walls, stone strings must correspond to the thickness of the bricks. Strings are generally bevelled, or weathered, upon the upper side, and grooved on the under side: the weathering is denominated *sunk work*, and the grooving, *throating*. Stone sills in common use are about 4¾ inches thick, and 8 inches broad; they are weathered at the top, which reduces the front, or vertical face, to about 4 inches, and the horizontal surface at top to about 1½ inch on the inside; so that the part taken away is 6½ inches broad, and three-quarters of an inch deep. Sills of windows, when inserted in the wall, most commonly project about 2½ inches. The horizontal plane part, left on the inside of the top, the vertical part, or face, and the horizontal part on the lower side without the wall, are denominated *plain work;* the sloping part is the *sunk work*. Plain and sunk work are measured by the foot superficial; throating by the foot run; and are thus entered in the measurer's book:

adding { 1½ / 4 / 2½ }

the sum is 8 inches for the breadth of the plain work in the sill, according to the dimensions stated.

Ft.	In.	
4	0	Plain work.
0	8	
4	0	Sunk work.
0	6½	
2 { 0	8	Plain to end.
0	4½	
4	0	Run of throating.

The sawing is not taken into account.

Cornices are measured by girting round the mouldings; that is, round all the vertical and under sides: this is denominated *moulded work.*

Thus, suppose a cornice to project one foot, and to girt two feet, and to be 40 feet in length; then the dimensions are entered as below:

Ft.	
40	Moulded work.
2	
40	Sunk work at top.
1	

To this must be added all the vertical joints.

All cylindrical work is measured in the girt, and the surface is acounted equivalent to plane work taken twice.

Thus, suppose a cylinder girts 4 feet 9 inches, and is in height 12 feet, then the dimensions are written as follow:

Ft.	In.	
12	0	Super plain work.
4	9	Double measure.

Rough stone, or marble, is measured by the foot cube; but for workmanship, the superficies are measured before it is sunk, for plain work; one bed, and one upright joint, are also accounted plain work, as before stated; then to take the plain sunk work, or circular, if any, and the straight moulded work, or circular moulded work, if there be any such. In taking the dimensions, particular care is required to distinguish these different species of work in the progressive state of preparing the stone. Throatings, and all narrow sinkings, are measured by the foot running measure. In taking the dimensions of moulded work, the mouldings must be girt with a string.

The contents of pavements, slabs, and chimney-pieces, are found by superficial measure; as also stones under two inches thick are valued according to the same measure; but those that are solid by the foot cube.

The construction of rubble-walls is not known in London, from the want of stone; but in many countries such erections are very general.

The standard thickness of rubble-wall is 2 feet; the content is first found in feet and inches, then divided by 9, which reduces it to superficial yards; and the yards are again divided by 36, which reduces it to roods, should the superficial content in yards admit of such division: when the wall is above 2 feet, it is reduced to that standard by adding one-eighth, one-fourth, one-half, according as the additional thickness may be 3 or 6 inches, or a foot.

Weight of Stone.

Purbeck stone,	14	cubic feet,	weight one ton.
Portland —	16	ditto	ditto
Bath —	17	ditto	ditto
Yorkshire —	15	ditto	ditto
Granite	13½	ditto	ditto
Marble	13	ditto	ditto
Purbeck paving	50	feet superficial	ditto
Ditto step 13 by 6½	25	feet run	ditto

Valuation of Labour.

Table of Constants for the different descriptions of mason s work.

N.B.—The factor to be applied is the rate of wages for a mason per day.

Labour.—Squaring and laying new York or Purbeck.

	Days.
Paving, per foot superficial	.021
If in courses, add	.010

Labour on Portland or similar, per foot superficial.

N.B.—Sawing to be taken as half plain work.

Plain work, to bond stones per foot superficial		.140
to beds and joints	ditto	.181
rubbed face	ditto	.209
ditto circular	ditto	.291
Sunk work, rubbed	ditto	.250
circular	ditto	.313
Moulded work, rubbed	ditto	.292
circular	ditto	.417

	Per foot superficial.	Days.
Circular work to shafts of columns, having the neck moulding, or part of the base, worked in the same stone	ditto	.334
Circular or spherical work to domes or balls	ditto	.500
If rubbed add extra	ditto	.049
Taking up, squaring, and re-laying old paving	ditto	.042
Add, if in courses,	ditto	.015

Labour on statuary or vein marble, including sawing, working, and polishing

	Per foot superficial.	Days.
Plain work	ditto	.875
Circular ditto	ditto	1.250
Sunk ditto	ditto	1.667
Moulded ditto	ditto	2.334
Circular sunk ditto	ditto	2.334
Circular moulded ditto	ditto	3.000
On Old Work.		
Old vein marble chimney re-set	ditto	.125
Ditto square and re-set	ditto	.167
Ditto sanded, grounded, and squared	ditto	.209
Ditto and re-set	ditto	.250
Ditto cleaned and re-set	ditto	.250
Ditto sanded, polished, and re-set	ditto	.350
Ditto sawed, sanded, polished, squared, and re-set	ditto	.626

Carpenters' Work.

Definition.—By carpenters' work is meant the measuring of common centres, groined centres, floors, partitions, centering, bond-timbers, lintels, wall-plates, and roofs.

For the general customs see the article Carpenters' work.

Problem I.—*To measure the centering of a cylindrical vault.*

Rule.—Multiply the length of the vault in feet, by the circumference of the arch, for the breadth; and divide the product by 100, if greater than the same, and the quotient will give the number of squares and feet.

Example I.—How many squares of centering are there in a vault, whose length is 18 feet 6 inches, and circumference 31 feet 6 inches?

By duodecimals.

Feet.	In.
31	6
18	6
248	0
310	0
9	0
15	6
0	3
582	9

By vulgar fractions.

$31\frac{1}{2}$
$18\frac{1}{2}$
$15\frac{1}{2}+\frac{1}{4}$
9
248
31
$5,82,\frac{3}{4}$

582 9 or 5 squares, 82 feet, 9 inches.

By decimals.

31.5
18.5
1575
2520
315
5,82.75

Problem II.—*To measure raked floors, whether for materials, or workmanship.*

Rule I.—If there be any number of pieces of timber of the same scantlings and length, and the solidity of one of them; and that solidity multiplied by the number of pieces will give the solidity of the whole.

Rule 2.—If the pieces be of the same scantling, but of different lengths, add all the different lengths together, multiply the sum by the area of the end of one of the pieces, and the product will give the solidity of the whole.

Rule 3.—If the pieces be of different scantlings, but of the same length, find the areas of the ends of all the pieces, and the sum of these areas being multiplied by the common length, will give the solidity of the whole number.

Rule 4.—If some of the pieces be of one scantling, equal among themselves, and others of the pieces of another scantling, equal among themselves, but all of the same length; multiply the area of the ends of each, by the number of such as are of the same scantling, add the products together, and their sum, multiplied by the common length, will give the solidity.

Rule 5.—If the lengths vary, as well as the scantlings, find the solidity of each piece separately, and the sum will give the solidity of the whole.

Note.—Wherever a tenon is made, the length of the piece must be taken from the ends of the tenons, and not from the shoulders.

If the floors be fixed in the building, the distance the timber goes into the wall, which is about one-third of the thickness of the wall, must be added to the length of the respective pieces that are clear of the walls.

The best method of finding the solidity of a joist, where the length is given in feet, inches, &c., and the dimension of the section in inches, is to multiply the inches together, and throw the twelves out of the product; also throw the twelves out of the length, and multiply these together.

Example.—Suppose a joist 15 feet long, 3 inches by 9; the product is 27, which divided by 12 gives 2 feet 3 inches; also 15 divided by 12 gives 1 foot 3 inches; then

1	3
2	3
2	6
	3 9
2	9 9

Suppose the girder, to be 1 foot broad, 1 foot 2 inches deep, and 20 feet long; there are eight bridging-joists, whose scantlings are 3 inches by $6\frac{1}{2}$ inches, and 20 feet long; that is, of the same length with the girder; there are also eight binding-joists, whose lengths are 9 feet, and their scantlings $8\frac{1}{2}$ inches by 4 inches; the ceiling-joists are 24 in number, each 6 feet long, 4 inches by $2\frac{1}{2}$ inches; required the solidity of the whole, either for materials or workmanship.

1	2			
1				
1	2			area of the end of the girder.
	6	6		
	3			
	1	7	6	area of the end of a bridging-joist.
	8			number of bridging-joists.
1	1	0	0	
add 1	2			the area of the end of the girder.
2	3			sum of the areas of the ends of the girder and bridging-joists.
20				common length.
45				feet, the solidity of the girder and bridging-joists.

8 6 depth.
4 thick.

2 10 0
9

2 1 6 solidity of a binding-joist.
8

17 feet, solidity of all the binding-joists.
2 6
4

10 0 area of the end of a ceiling-joist.
6

5 inches, solidity of a ceiling-joist.
24 number of ceiling-joists.

10 feet, solidity of the ceiling-joists.
17
45

72 feet, sum of all the solidities in the whole floor.

PROBLEM III.—*To measure roofing, or partitions, either for materials or workmanship.*

All timbers in a roof, or partition, are measured in the same manner as floors, excepting king-posts and queen-posts, &c., when there is a necessity for cutting out parallel pieces of wood from their sides, in order that the ends of such braces as come against them may have, what is called by workmen, a *square butment.* To measure the workmanship of such pieces, or posts, take their breadth and depth, at the widest part, multiply them by the length, and the product will give the solidity for workmanship. To find the quantity of materials, if the pieces sawn out are $2\frac{1}{2}$ inches thick, or more, they are esteemed pieces of timber fit for use; when more than two feet long, their lengths should not be esteemed so long by 5 or 6 inches, because the saw cannot enter the wood with much less waste, and consequently the pieces must be deducted from the whole solidity, and the remainder will give the quantity of materials; but if the pieces cut out be less than $2\frac{1}{2}$ inches, the whole post must be measured as solid for the materials, because pieces cut out are of little use.

Example.—Let the tie-beam be 36 feet long, 9 inches wide, by 1 foot 2 inches deep; the king-post, is 11 feet 6 inches high, 1 foot broad at the bottom, by 5 inches thick: out of this are sawn two pieces from the sides, 3 inches thick and 7 feet long; the braces, are 7 feet 6 inches long, 5 inches by 5 inches; the rafters are 19 feet long, 10 inches by 5 inches each; the struts are 3 feet 6 inches long, and 4 inches by 5 inches; required the measurement for workmanship, and also for materials.

1 2
9

10 6
3

31 6 solidity of the tie-beam.

5
5

2 1
15 lengths of the two braces added together.

2 7 3

5
10

4 2
3 2

8 4
12 6

13 2 4 solidity of both rafters.

1
5

5
11 6

4 9 6 solidity of the king-post, as if solid.

3
5

1 3
7

8 9 solidity of the two pieces cut from the sides.

4
5

1 8
7

11 8 solidity of the struts.

Consequently,

Feet.	In.	"	
31	6	0	tie-beam.
2	7	3	braces.
18	2	4	rafters.
4	9	6	king-post.
	11	8	solidity of the struts.
53	0	9	solidity of the roof for work-
	8	9	manship.
52	4	0	solidity for materials.

VALUATION OF CARPENTERS' AND JOINERS' WORK.

Memoranda.

50 cubic feet of timber equal one load.
100 feet superficial, equal one square.
120 deals are called one hundred.
A reduced deal is $1\frac{1}{2}$ in. thick, 11 inches wide, and 12 ft. long
120 12 feet 3 inch deals, equal $5\frac{2}{3}$ loads of timber.
400 feet superficial of $1\frac{1}{2}$ in. plank or deals, equal one load.
Planks are 11 inches wide, deals 9 inches and battens 7 inches.

A square of flooring requires—	Number of 12 feet boards.
Laid rough	$12\frac{1}{4}$
Ditto edges shot	$12\frac{1}{2}$
Wrought and laid folding	13
— straight joint	$13\frac{1}{2}$
— — and ploughed and tongued	14
	Number of 12 feet battens.
One square of wrought folding floors requires	17
Ditto straight joint	18

Weight of Timber.

39	cubic feet of	oak	equal	1 ton.
65	—	fir	—	do.
66	—	deals	—	do.
60	—	elm	—	do.
51	—	beech	—	do.
45	—	ash	—	do.
35	—	mahogany	—	do.

JOINERS' WORK.

In boarded flooring, the dimensions must be taken to the very extreme parts, and from thence the squares are to be computed; out of which deductions are to be made for staircases, chimneys, &c.

Weather-boarding is done by the yard square, and sometimes by the square, containing 100 superficial feet.

Boarded partitions are measured by the square; out of which must be deducted the doors and windows, except they are agreed to be included.

Windows are generally made and valued by the foot superficial, and sometimes by the window. When they are measured, the dimensions must be taken in feet and inches, from the under side of the sill to the upper side of the top rail, for the height; and for the breadth, from outside to outside of the jambs; the product of these is the superficial content. For farther particulars, see the article JOINERY.

Example.—How many feet does a piece of dwarf wainscoting contain, that is 18 feet 7 inches long, and 5 feet 3 inches high?

By cross multiplication.	By decimals.
18 6	18.5
5 3	5.25
1 6	925
54	370
30	925
12) 85	97.125
7 1	
90	
97 1 6	

PAINTERS' WORK.

This work is measured by the yard square, and the dimensions are taken in feet, inches, and tenths.

In painters' work, every part that is coloured is measured; consequently the dimensions must be taken with a line girt over the mouldings. Ornamental work must be paid double measure; and if carved, at per value, according to the time.

Iron or wood railings, balusters, &c., to be measured on both sides as solid work, at per yard superficial. The following contracts may be used for common work—

First coat, including stopping	.027
Second, and following coats	.019

PLASTERERS' WORK.

This is done by the yard square, and the dimensions are taken in feet and inches.

When a room consists of more than four quoins, the additional corners must be allowed at per foot run.

In measuring ceilings with ribs, the superficies must first be taken for the plain work; then an allowance must be made for each mitre, and the ribs must be valued at so much per foot run, according to the girt, or by the foot superficial, allowing moulded work.

In measuring common work, the principal things to be observed are as follow:

1. To make deductions for chimneys, windows, and doors.
2. To make deductions for rendering upon brickwork, for doors and windows.
3. If the workman find materials for rendering between quarters, one-fifth must be deducted for quarters; but if workmanship only is found, the whole must be measured as whole work, because the workman could have performed the whole much sooner, if there had been no quarters.
4. All mouldings in plaster work are done by the foot superficial, as joiners do, by girting over the mouldings with a line.

When rooms have cornices, measure the ceiling or walls, including half the width or height of the cornice respectively, except when the cornices are bracketed, and then only measure up to them. In measuring the length of cornices, take the size of the room, taking one projection in and one out, and girt the cornices. Enriched friezes, &c., must be measured first as plain work, and the enrichments taken separately afterwards.

Valuation of Plasterers' Work.—Calculation of Materials.

1 hundred of lime = 25 striked bushels (old measure).

	Materials.	Labour.
100 yards of render set require	$1\frac{1}{2}$ hod. of lime. 1 double load of sand. 4 bushels of hair.	Plasterer, Labourer and Boy, 3 days each.

	Materials.	Labour.
130 yards of lath plaster, and set require	1 load of laths. 10,000 nails. $2\frac{1}{2}$ hds. of lime. $1\frac{1}{2}$ dble. lds. of sand. 7 bushels of hair.	Plasterer, Labourer, and Boy, 6 days each.

Lathing.

1 bundle of laths and 384 nails will cover 5 yards.

Render only.

$187\frac{1}{2}$ yards require . . . . . $1\frac{1}{2}$ hod. of lime.; 2 double loads of sand.; 5 bushels of hair.

Floating requires more labour, but not more than half the quantity of stuff as rendering.

Setting only.

375 yards require . . . . $1\frac{1}{2}$ hod. of lime.; 5 bushels of hair.

20 per cent. is always allowed on the prime cost of the materials.

Calculation of Labour.

The decimal is to be multiplied by the rate of wages for plasterer, labourer, and boy, per day.

	Days.
Rough render	.019
Floating render	.021
Setting	.016
Lathing	.019
If circular work, add on the lathing, and also on each coat of plastering	.008
If to groins, add as before	.001

GLAZIERS' WORK.

Glaziers' work is measured by the foot superficial, and the dimensions are taken in feet, tenths, hundredths, &c. For this purpose, their rules are generally divided into decimal parts, and their dimensions squared according to decimals.

Circular, or oval windows, are measured as if they were rectangular; because in cutting the squares of glass there is a very great waste, and more time is expended than if the windows had been of a rectangular form.

Example.—How many feet superficial of glazing does a window contain, that is 7.25 high and 3.75 wide?

7.25
3.75

3625
5075
2175

27.1875 feet, the answer.

Plumbers' Work.

This is generally done by the pound, or hundredweight.

Sheet lead, used in roofing, for guttering and valleys, is in weight from 7lb. to 12lb. per foot; and for ridges from 6lb. to 8lb.

The following table will show the weight of a foot, according to several thicknesses.

The thickness is set in tenths and hundredths of an inch, in the first vertical column; and the weight opposite, in the same horizontal line, in the second vertical column on the right hand: the integers show the number of pounds avoirdupois, and the decimals the number of thousandth parts above the integer: so that the weight of a square foot of $\frac{1}{10}$ or .10 of an inch thick is 5lb. and 899 thousandth-parts.

Thickness.	lbs. to a sq. foot.
.10	5.899
.11	6.489
$\frac{1}{9}$ = .11 &c.	6.554
.12	7.078
$\frac{1}{8}$ = .125	7.373
.13	7.668
.14	8.258
$\frac{1}{7}$ = .14 &c.	8.427
.15	8.848
.16	9.438
$\frac{1}{6}$ = .16 &c.	9.831
.17	10.028
.18	10.618
.19	11.207
$\frac{1}{5}$ = .20	11.797
.21	12.387

Example.—What is the weight of a sheet of lead, 25 feet 6 inches long, and 3 feet 3 inches broad; at 8½lb. to the square foot?

3.25
25.5

1625
1625
650

82.875
8.5

414375
663000

704.4375lbs., as required.

Lead-headed nails, wall-hooks, and hold-fasts, are charged at per piece; clout-nails by the hundred: all kinds of pipes are charged at per foot run according to size of bore. Washers, plugs, valves, &c., at so much each. Joints are charged separately.

Paviors' Work.

Paviors' work is done by the square yard.

Example.—Suppose a pathway to be 45 feet 6 inches long, and the breadth 12 feet 3 inches; how many square yards does it contain?

45.5 length.
12.25 breadth.

2275
910
910
455

9) 557.375

61.930 the number of yards required.

The decimals will be reduced to feet by multiplying them by 9; thus,

.930
9

8.370 feet.

It is not necessary to go any farther, as the value of the next denomination is not worth the trouble.

Slaters' Work.

If the roof be equally hipped on all sides with a flat at top, and the plan of the building be rectangular, add the length and breadth of two adjoining sides at the eaves, and the length and breadth of two adjoining sides of the flat together; multiply the sum by the breadth of the slope, and the product will give the area of the space that is covered.

Add the number of square feet produced by multiplying the girt of the roof by the length of a slate at the eaves, to the area, for the trouble of putting on the double row of slates; also add the number of square feet produced by multiplying the length of the hips by one foot in breadth, for the trouble of cutting the slates where they meet, to the said area; and the sum will be the whole contents, so as to make a compensation for the trouble and waste of materials.

Example.—Suppose a house 40 feet 6 inches in width and 60 feet 3 inches in length; the breadth of the slope 15 feet 9 inches, the breadth of the flat 12 feet, and the length 31 feet 9 inches.

Ft.	In.	
40	6	
60	3	
12	0	
31	9	
144	6	
15	9	
	4	6
	1296	
	90	
12)	1390	
	115	10
	720	
	144	
2275	10	6 the area.

To this area add the allowances for workmanship and waste.

If there be no flat, add the two adjoining sides and twice the length of the ridge, for the length; multiply the sum by the breadth of the slope, for the area of the space covered; then add the allowances as before.

Mensuration of Timber.

The following rules are from Dr. Hutton's Mensuration.

"Problem I.—*To find the area or superficial feet in a board or plank.*

"Rule.—Multiply the length by the mean breadth.

"*Note.*—When the board is tapering, add the breadth at the two ends together, and take half the sum for the mean breadth.

By the sliding rule.—Set 12 on B to the breadth in inches on B; then against the length in feet on B, is the content on A, in feet and fractional parts.

"*Example* 1.—What is the value of a plank, whose length is 12 feet 6 inches, and mean breadth 11 inches; at $1\frac{1}{2}d.$ per square foot?

By decimals.

12.5
11

12 | 137.5
$1\frac{1}{2}d.$ is $\frac{1}{8}$ | 11.46

1*s.* 5*d.* ans.

By duodecimals.

12 6
11

$1\frac{1}{2}d.$ is $\frac{1}{8}$ | 11 5 6

1*s.* $4\frac{1}{2}d.$
5 in. is 0 $\frac{1}{2}$

1*s.* 5d.

"*By the sliding rule.*

"As 12B : 11A :: $12\frac{1}{2}$B : $11\frac{1}{2}$A.

"That is, as 12 on B is to 11 on A, so is $12\frac{1}{2}$ on B to $11\frac{1}{2}$ on A.

"*Example* 2.—Required the content of a board, whose length is 11 feet 2 inches, and breadth 1 foot 10 inches.—Answer, 20 feet, 5 inches, and 8 seconds.

"*Example* 3.—What is the value of a plank, which is 12 feet 9 inches long, and 1 foot 3 inches broad, at $2\frac{1}{2}d.$ a foot—Answer, $3s.$ $3\frac{3}{4}d.$

"*Example* 4.—Required the value of five oaken planks, at $3d.$ per foot, each of them being $17\frac{1}{2}$ feet long; and their several breadths as follow, namely, two of $13\frac{1}{2}$ inches in the middle; one of $14\frac{1}{4}$ inches in the middle, and the two remaining ones, each 18 inches at the broader end, and $11\frac{1}{4}$ at the narrower.—Answer, £1 $5s.$ $8\frac{1}{4}d.$

"Problem II.—*To find the solid content of squared or four-sided timber.*

Rule.—Multiply the mean breadth by the mean thickness, and the product again by the length, and the last product will give the content.

"*By the sliding rule.*

C D D C

"As length : 12 or 10 :: quarter girt : solidity.

"That is, as the length in feet on C, is to 12 on D when the quarter girt is in inches, or to 10 on D when it is in tenths of feet; so is the quarter girt on D, to the content on C.

"*Note* 1.—If the tree taper regularly from the one end to the other, either take the mean breadth and thickness in the middle, or take the dimensions at the two ends, and then half their sum for the mean dimensions.

"2. If the piece do not taper regularly, but is unequally thick in some parts, and small in others, take several different dimensions, add them all together, and divide their sum by the number of them, for the mean dimensions.

"3. The quarter-girt is a geometrical mean proportional between the mean breadth and thickness; that is, the square root of their product. Sometimes unskilful measurers use the arithmetical mean instead of it, that is, half their sum; but this is always attended with error, and the more so as the breadth and depth differ the more from each other.

"*Example* 1.—The length of a piece of timber is 18 feet 6 inches, the breadth at the greater and less end 1 foot 6 inches and 1 foot 3 inches, and the thickness at the greater and less end 1 foot 3 inches and 1 foot: required the solid content.

Decimals.		Duodecimals.
1.5		1 6
1.25		1 3
2) 2.75		2) 2 9
1.375	mean breadth	1 4 6
1.25		1 3
1.0		1 0
2) 2.25		2) 2 3
1.125	mean depth	1 1 6
1.375	mean breadth	1 4 6
5625		1 1 6
7875		4 6
3375		
1125		6 9
1.546875		1 6 6 9
18.5	length	18 6
7734375		27 10 1 6
12375000		9 3 4
1546875		
28.6171875	content	28 7 4 10

"*By the sliding rule.*

B A B A

"As 1 : $13\frac{1}{2}$ :: $16\frac{1}{2}$: 223, the mean square.

C D C D

"As 1 : 1 :: 223 : 14.9, quarter-girt.

C D D C

"As $18\frac{1}{2}$: 12 :: 14.9 : 28.6, the content.

"*Example* 2.—What is the content of the piece of timber, whose length is $24\frac{1}{2}$ feet, and the mean breadth and thickness each 1.04 feet?—Answer, $26\frac{1}{2}$ feet.

"*Example* 3.—Required the content of a piece of timber, whose length is 20.38 feet, and its ends unequal squares, the side of the greater being $19\frac{1}{8}$ inches, and the side of the less $9\frac{7}{8}$ inches.—Answer, 29.7562 feet.

"*Example* 4.—Required the content of a piece of timber, whose length is 27.36 feet; at the greater end the breadth is 1.78, and thickness 1.23; and at the less end the breadth is 1.04, and thickness 0.91?—Answer, 41.278 feet.

"Problem III.—*To find the solidity of round or unsquared timber.*

"Rule 1, or Common Rule.—Multiply the square of the quarter-girt, or of one-fourth of the mean circumference, by the length, for the content.

"*By the sliding rule.*—As the length upon C : 12 or 10 upon D : : quarter girt in 12ths or 10ths, on D : content on C.

"*Note* 1.—When the tree is tapering, take the mean dimensions, as in the former Problems, either by girting it in the middle for the mean girt, or at the two ends, and take half the sum of the two. But when the tree is very irregular

divide it into several lengths, and find the content of each part separately.

"2. This rule, which is commonly used, gives the answer about one-fourth less than the true quantity in the tree, or nearly what the quantity would be after the tree is hewed square in the usual way; so that it seems intended to make an allowance for the squaring of the tree. When the true quantity is desired, use the second rule given below.

"*Example* 1.—A piece of round timber being 9 feet 6 inches long, and its mean quarter-girt 42 inches; what is the content?

Decimals.		Duodecimals.
3.5	quarter girt	3 6
3.5		3 6
175		10 6
105		1 9
12.25		12 3
9.5	length	9 6
6125		110 3
11025		6 1 6
116.375	content	116 4 6

"*By the sliding rule.*

C		D		D		C
As 9.5	:	10	: :	35	:	$116\frac{1}{3}$
Or 9.5	:	12	: :	42	:	$116\frac{1}{3}$

"*Example* 2.—The length of a tree is 24 feet, its girt at the thicker end 14 feet, and at the smaller end 2 feet; required the content.—Answer 96 feet.

"*Example* 3.—What is the content of a tree, whose mean girt is 3.15 feet, and length 14 feet 6 inches?—Answer, 8.9922 feet.

"*Example* 4.—Required the content of a tree, whose length is $17\frac{1}{4}$ feet, and which girts in five different places as follows, namely, in the first place 9.43 feet, in the second 7.92, in the third 6.15, in the fourth 4.74, and in the fifth 3.16.—Answer, 42,5195.

"Rule 2.—Multiply the square of one-fifth of the mean girt by double the length, and the product will be the content, very near the truth.

"*By the sliding rule.*—As the double length on C : 12 or 10 on D : : $\frac{1}{5}$ of the girt, in 12ths or 10ths, on D : content on C.

"*Example* 1.—What is the content of a tree, its length being 9 feet 6 inches, and its mean girt 14 feet?

Decimals.		Duodecimals.
2.8	$\frac{1}{5}$ of girt	2 9 7
2.8		2 9 7
224		5 7 2
56		2 1 3
7.84		1 8
19		
7056		7 10 1
784		19
148.96	content	148 11 7

"*By the sliding rule.*

C		D		D		C
As 19	:	10	: :	28	:	149.
Or 19	:	12	: :	$33\frac{6}{10}$	:	149.

"*Example* 2.—Required the content of a tree, which is 24 feet long, and mean girt 8 feet.—Answer, 122.88 feet.

"*Example* 3.—The length of a tree is $14\frac{1}{2}$ feet, and mean girt 3.15 feet; what is the content?—Answer, 11.51 feet.

"*Example* 4.—The length of a tree is $17\frac{1}{4}$ feet, and its mean girt 6.28; what is the content?—Answer, 54.4065 feet.

"*Note* 1.—That part of a tree, or of the branches, which is less than 2 feet in circumference, or 6 inches quarter-girt, is cut off; not being accounted timber.

"2.—Fifty cubic feet of timber make a load; and therefore, to reduce feet to loads, divide them by 50."

Example.—How many loads of timber are there in 248 feet?

5,0) 24,8

4 48

So that this quantity contains four loads and 48 feet.

It is customary, however, to make a difference between square and round timber, in many places. The load of round timber containing 50 cubic feet, while that of square timber contains only 40. This allowance is reasonable, on account of the waste.

"A Table,

"*For readily finding the Content of Trees, according to the common Method of Measuring Timber.*

"Rule.—Seek the quarter-girt in the first column towards the left-hand, and take out the number opposite. Multiply that number by the length of the tree in feet, &c., and the product will be the content in solid feet, &c.

In.	Ft. In. ″ ‴ ⁗	In.	Ft. In. ″ ‴ ⁗	In.	Ft. In. ″ ‴ ⁗	In.	Ft. In. ″ ‴ ⁗	In.	Ft. In. ″ ‴ ⁗	In.	Ft. In. ″ ‴ ⁗
6	0 3 0 0 0	$10\frac{1}{2}$	0 9 2 3 0	15	1 6 9 0 0	$19\frac{1}{2}$	2 7 8 3 0	24	4 0 0 0 0	$28\frac{1}{2}$	5 7 8 3 0
$\frac{1}{4}$	0 3 3 0 9	$\frac{3}{4}$	0 9 7 6 9	$\frac{1}{4}$	1 7 4 6 9	$\frac{3}{4}$	2 8 6 0 9	$\frac{1}{4}$	4 1 0 0 9	$\frac{3}{4}$	5 8 10 6 9
$\frac{1}{2}$	0 3 6 3 0	11	0 10 1 0 0	$\frac{1}{2}$	1 8 0 3 0	20	2 9 4 0 0	$\frac{1}{2}$	4 2 0 3 0	29	5 10 1 0 0
$\frac{3}{4}$	0 3 9 6 9	$\frac{1}{4}$	0 10 6 6 9	$\frac{3}{4}$	1 8 8 0 9	$\frac{1}{4}$	2 10 2 0 9	$\frac{3}{4}$	4 3 0 6 9	$\frac{1}{4}$	5 11 3 6 9
7	0 4 1 0 0	$\frac{1}{2}$	0 11 0 3 0	16	1 9 4 0 0	$\frac{1}{2}$	2 11 0 3 0	25	4 4 1 0 0	$\frac{1}{2}$	6 0 6 3 0
$\frac{1}{4}$	0 4 4 6 9	$\frac{3}{4}$	0 11 6 0 9	$\frac{1}{4}$	1 10 0 0 9	$\frac{3}{4}$	2 11 10 6 9	$\frac{1}{4}$	4 5 1 6 9	$\frac{3}{4}$	6 1 9 0 9
$\frac{1}{2}$	0 4 8 3 0	12	1 0 0 0 0	$\frac{1}{2}$	1 10 8 3 0	21	3 0 9 0 0	$\frac{1}{2}$	4 6 2 3 0	30	6 3 0 0 0
$\frac{3}{4}$	0 5 0 0 9	$\frac{1}{4}$	1 0 6 0 9	$\frac{3}{4}$	1 11 4 6 9	$\frac{1}{4}$	3 1 7 6 9	$\frac{3}{4}$	4 7 3 0 9	$\frac{1}{4}$	6 4 3 0 9
8	0 5 4 0 0	$\frac{1}{2}$	1 1 0 3 0	17	2 0 1 0 0	$\frac{1}{2}$	3 2 6 3 0	26	4 8 4 0 0	$\frac{1}{2}$	6 5 6 3 0
$\frac{1}{4}$	0 5 8 0 9	$\frac{3}{4}$	1 1 6 6 9	$\frac{1}{4}$	2 0 9 6 9	$\frac{3}{4}$	3 3 5 0 9	$\frac{1}{4}$	4 9 5 0 9	$\frac{3}{4}$	6 6 9 6 9
$\frac{1}{2}$	0 6 0 3 0	13	1 2 1 0 0	$\frac{1}{2}$	2 1 6 3 0	22	3 4 4 0 0	$\frac{1}{2}$	4 10 6 3 0	31	6 8 1 0 0
$\frac{3}{4}$	0 6 4 6 9	$\frac{1}{4}$	1 2 7 6 9	$\frac{3}{4}$	2 2 3 0 9	$\frac{1}{4}$	3 5 3 0 9	$\frac{3}{4}$	4 11 7 6 9	$\frac{1}{4}$	6 9 4 6 9
9	0 6 9 0 0	$\frac{1}{2}$	1 3 2 3 0	18	2 3 0 0 0	$\frac{1}{2}$	3 6 2 3 0	27	5 0 9 0 0	$\frac{1}{2}$	6 10 8 3 0
$\frac{1}{4}$	0 7 1 6 9	$\frac{3}{4}$	1 3 9 0 9	$\frac{1}{4}$	2 3 9 0 9	$\frac{3}{4}$	3 7 1 6 9	$\frac{1}{4}$	5 1 10 6 9	$\frac{3}{4}$	7 0 0 0 9
$\frac{1}{2}$	0 7 6 3 0	14	1 4 4 0 0	$\frac{1}{2}$	2 4 6 3 0	23	3 8 1 0 0	$\frac{1}{2}$	5 3 0 3 0	32	7 1 4 0 0
$\frac{3}{4}$	0 7 11 0 9	$\frac{1}{4}$	1 4 11 0 9	$\frac{3}{4}$	2 5 3 6 9	$\frac{1}{4}$	3 9 0 6 9	$\frac{3}{4}$	5 4 2 0 9	$\frac{1}{4}$	7 2 8 0 9
10	0 8 4 0 0	$\frac{1}{2}$	1 5 6 3 0	19	2 6 1 0 0	$\frac{1}{2}$	3 10 0 3 0	28	5 5 4 0 0	$\frac{1}{2}$	7 4 0 3 0
$\frac{1}{4}$	0 8 9 0 9	$\frac{3}{4}$	1 6 1 6 9	$\frac{1}{4}$	2 6 10 6 9	$\frac{3}{4}$	3 11 0 0 9	$\frac{1}{4}$	5 6 6 0 9	$\frac{3}{4}$	7 5 4 6 9

SCHOLIUM.—In measuring squared timber, unskilful measurers usually take one-fourth of the circumference, or girt, for the side of a mean square; which quarter girt therefore multiplied by itself, and the product multiplied by the length, they account the solidity, or content: when the breadth and thickness are nearly equal, this method will give the solidity pretty near the truth; but if the breadth and thickness differ considerably, the error will be so great, that it ought by no means to be neglected.

"Thus, suppose we take a balk, 24 feet long, and a foot square throughout; and consequently its solidity 24 cubic feet: if this balk be slit exactly in two, from end to end, making each piece 6 inches broad, and 12 inches thick, the true solidity of each will be 12 feet; but, by the quarter-girt method, they would amount to much more; for the false quarter girt, being equal to half the sum of the breadth and thickness, in this case will be 9 inches, the square of which is 81, which being divided by 144, and the quotient multiplied by 24, the length, we obtain $13\frac{1}{2}$ feet for the solidity of each part; and consequently the two solidities together make 27 feet, instead of 24.

"Again, suppose the balk to be so cut, that the breadth of one piece may be 4 inches, and that of the other 8 inches. Here the true content of the less piece will be 8 feet, and that of the greater 16 feet. But, proceeding by the other method, the quarter-girt of the less piece will be 8, whose square, 64, multiplied by 24, and the product divided by 144, gives $10\frac{2}{3}$ feet instead of 8. And by the same method, the content of the greater piece will be $16\frac{2}{3}$ feet, instead of 16. And the sum of both is $27\frac{1}{3}$ feet, instead of 24 feet.

"Farther, if the less piece be cut only 2 inches broad, and the greater 10 inches; the true content of the less piece would be 4 feet, and that of the greater 20. But, by the other method, the quarter-girt of the less piece would be 7 inches, whose square, 49, being divided by 6, gives $8\frac{1}{6}$ feet, instead of 4, for the content. And, by the same method, the content of the greater piece would be $20\frac{1}{6}$, instead of 20 feet. So that their sum would be $28\frac{1}{3}$, instead of 24 feet.

"Hence it is evident, that the greater the proportion between the breadth and depth, the greater will the error be, by using the false method; that the sum of the two parts, by the same method, is greater, as the difference of the same two parts is greater, and consequently the sum is least when the two parts are equal to each other, or when the balk is cut equally in two; and lastly, that when the sides of a balk differ not above an inch or two from each other, the quarter-girt method may then be used, without inducing an error that will be of any material consequence.

"PROBLEM IV.—*To find where a piece of round tapering timber must be cut, so that the two parts, measured separately, according to the common method of measuring, shall produce a greater solidity than when cut in any other part, and greater than the whole.*

"RULE.—Cut it through exactly in the middle, or at half of the length, and the two parts will measure to the most possible, by the common method.

"*Example.*—Supposing a tree to girt 14 feet at the greater end, 2 feet at the less, and consequently 8 feet in the middle; and that the length is 32 feet.

"Then, by the common method, the whole tree measures to only 128 feet; but when cut through at the middle, the greater part measures 121, and the less part to 25 feet; whose sum is 146 feet; which exceeds the whole by 18 feet, and is the most that it can be made to measure to by cutting it into two parts.

"DEMONSTRATION.—Put G = the greatest girt, g = the least, and x = the girt at the section; also L = the whole length, and z = the length to be cut off the less end.

"Then, by similar figures, $L : z :: G - g : x - g$. Hence $x = \frac{G z - g z}{L} + g$. But $(g + x)^2 . z + (G + x)^2 . (L - z)$ = a maximum; whose fluxion being put equal to nothing, and the value of x substituted instead of it, there results $z = \frac{1}{2}$ L. Q. E. D.

"COROLLARY.—By thus bisecting the length of a tree, and then each of the parts, and so on, continually bisecting the lengths of the several parts, the measure of the whole will be continually increased.

"PROBLEM V.—*To find where a tree should be cut, so that the part next the greater end may measure to the most possible.*

"RULE.—From the greater girt take 3 times the less; then, as the difference of the girts is to the remainder, so is one-third of the whole length, to the length from the less end to be cut off.

"Or, cut it where the girt is one-third of the greatest girt.

"*Note.*—If the greatest girt do not exceed three times the least, the tree cannot be cut as is required by this problem. For, when the least girt is exactly equal to one-third of the greater, the tree already measures to the greatest possible; that is, none can be cut off, nor indeed added to it, continuing the same taper, that the remainder or sum may measure to so much as the whole: and when the least girt exceeds one third of the greater, the result by the rule shows how much in length must be added, that the result may measure to the most possible.

"*Example.*—Taking here the same example as before, we shall have, as $12 : 8 :: \frac{3}{3\frac{1}{2}} : 7\frac{1}{9}$ = the length to be cut off; and consequently the length of the remaining part is $24\frac{8}{9}$; also $\frac{1}{3}^4 = 4\frac{2}{3}$ is the girt of the section. Hence the content of the remaining part is $135\frac{4}{81}$ feet; whereas the whole tree, by the same method, measures only to 128 feet.

"DEMONSTRATION.—Using the same notation as in the last demonstration; we have here also $x = \frac{G z - g z}{L} + g$, and $(G + x)^2 . (L - x)$ = a maximum; which, treated as before, gives $z = \frac{G - 3g}{G - g} \times \frac{1}{3}$ L. And $x = \frac{G - g}{L} z + g \frac{1}{3}$ G, by substituting the above value of z. Q. E. D.

"PROBLEM VI.—*To cut a tree so as that the part next the greater end may measure, by the common method, to exactly the same quantity as the whole measures to.*

RULE.—Call the sum of the girts of the two ends s, and their difference d, then multiply by the sum of d and $4s$, thus:

$$d \times (d + 4s).$$

From the root of the product take the difference between d and $2s$, thus:

$$\surd (d^2 + 4ds) - 2s + d.$$

Then, As twice d—is to the remainder,
So is the whole length—to the length to be cut off.

Thus calling the whole length L, and the part to be cut off l, we have:

$$2d : \sqrt{(d^2 + 4ds)} - 2s + d :: L : l = \frac{L}{2d} \times (\sqrt{(d^2 + 4ds)} - 2s + d).$$

Example.—Using still the same numbers as in the preceding examples, we have, $s = 16$, $d = 12$, and $L = 32$.

$$l = \frac{L}{2d} \times (\sqrt{(d^2 + 4ds)} - 2s + d) = \frac{32}{2 \times 12} \times (\sqrt{(12^2 + 4 \times 12 \times 16)} - 2 \times 16 + 12) = \frac{4}{3} \times (\sqrt{(144 + 768)} - 20) \frac{4}{3} \times (\sqrt{(912)} - 20) = \frac{4}{3} \times (30.1993377 - 20) = \frac{4}{3} \times 10.199337 = 13.5991198$$ the length to be cut off.

Therefore the length of the remaining part is 32 — 13.5991168 = 18.4008832.

And if s be taken from the root, viz. $\sqrt{(d^2 + 4ds)}$ half the remainder will be the girt of the section. Therefore, according to the numbers given, the girt of the section $\frac{\sqrt{(d^2 + 4ds)} - s}{2} = \frac{30.1993377 - 16}{2} = 7.0996688.$

Hence the girt in the middle of the greater part is $\frac{14 + 7.099669}{2} = 10.549834$, whose fourth part is 2.637458; and consequently the content of the same part is $2.637458^2 \times 18.40083 = 128$, the very same as the whole tree measures to, notwithstanding above one-third part is cut off the true length.

"*Note.*—The principles of these last three Problems are also applicable to the new, or second rule, in page 361, and indeed to any other approximate rule, or such as is not founded on the rule for the frustum of a cone.

"Demonstration.—Using still the same notation, we shall have $s^2 L = (L - 2) \times (G + x)^2$; hence, instead of x, substituting its value $\frac{dz}{L} + g$, we obtain $z = \frac{L}{2d} \times (\sqrt{(4s + d)}. d) - (2s + d)$.

"And hence $x = \frac{1}{2}(\sqrt{(4s + d)}. d) - \frac{1}{2}s.$ Q. E. D."

Rules have already been given for measuring the areas of circular segments, which may at least be depended upon to three places of figures, and which we have thought sufficiently correct for most practical purposes; but where greater accuracy is required, the following Table will carry the approximation to five or six figures.

The construction which comes after the Table depends upon the following series for the segment of a circle.

The area of the segment is $A + \frac{A v}{5 v} - \frac{1 B v}{7 v} + \frac{3 C v}{9 v} - \frac{5 D v}{11 v} + \frac{7 E v}{13 v}$, &c. where $A = \frac{4v}{3}\sqrt{v v}$, B, the second, C the third, &c. *See* also Rules 3 and 4, Theorem XI., page 171, which are the same in principle as this.

A Table

Of the Areas of the Segments of a Circle, whose diameter is Unity, and supposed to be divided into 1000 *equal Parts.*

Height.	Area Seg.	Height.	Area Seg.	Height.	Area Seg.	Height.	Area Seg.
.001	.000042	.075	.026761	.149	.073161	.223	.130605
.002	.000119	.076	.027289	.150	.073874	.224	.131438
.003	.000219	.077	.027821	.151	.074587	.225	.132272
.004	.000337	.078	.028356	.152	.075306	.226	.133108
.005	.000470	.079	.028894	.153	.076026	.227	.133945
.006	.000618	.080	.029435	.154	.076740	.228	.134784
.007	.000779	.081	.029979	.155	.077469	.229	.135624
.008	.000951	.082	.030526	.156	.078194	.230	.136465
.009	.001135	.083	.031076	157	.078921	.231	.137307
.010	.001329	.084	.031629	.158	.079649	.232	.138150
.011	.001533	.085	.031186	.159	.080380	.233	.138995
.012	.001746	.086	.032745	.160	.081112	.234	.139841
.013	.001968	.087	.033307	.161	.081846	.235	.140688
.014	.092199	.088	.033872	.162	.082582	.236	.141537
.015	.002438	.089	.034441	.163	.083320	.237	.142387
.016	.002685	.090	.035011	.164	.084059	.238	.143238
.017	.002940	.091	.035585	.165	.084801	.239	.144091
.018	.003202	.092	.036162	.166	.085544	.240	.144944
.019	.003471	.093	.036741	.167	.086289	.241	.145799
.020	.003748	.094	.037323	.168	.087036	.242	.146655
.021	.004031	.095	.037909	.169	.087785	.243	.147512
.022	.004322	.096	.038497	.170	.088535	.244	.148371
.023	.004618	.097	.039087	.171	.089287	.245	.149230
.024	.004921	.098	.039680	.172	.090041	.246	.150091
.025	.005230	.099	.040276	.173	.090797	.247	.150953
.026	.005546	.100	.040875	.174	.091554	.248	.151816
.027	.005867	.101	.041476	.175	.092313	.249	.152680
.028	.006194	.102	.042080	.176	.093074	.250	.153546
.029	.006527	.103	.042687	.177	.093836	.251	.154412
.030	.006865	.104	.043296	.178	.094601	.252	.155280
.031	.007209	.105	.043908	.179	.095366	.253	.156149
.032	.007558	.106	.044522	.180	.096134	.254	.157019
.033	.007913	.107	.045139	.181	.096903	.255	.157890
.034	.008273	.108	.045789	.182	.096674	.256	.158762
.035	.008638	.109	.046381	.183	.098447	.257	.159636
.036	.009008	.110	.047005	.184	.099221	.258	.160510
.037	.009383	.111	.047632	.185	.099997	.259	.161386
.038	.009763	.112	.048262	.186	.100774	.260	.162263
.039	.010148	.113	.048894	.187	.101553	.261	.163140
.040	.010537	.114	.049528	.188	.102334	.262	.164019
.041	.010931	.115	.050165	.189	.103116	.263	.164899
.042	.011330	.116	.050804	.190	.103900	.264	.165780
.043	.011734	.117	.051046	.191	.104685	.265	.166663
.044	.012142	.118	.052090	.192	.105472	.266	.167546
.045	.012554	.119	.052736	.193	.106261	.267	.168430
.046	.012971	.120	.053380	.194	.107051	.268	.169315
.047	.013392	.121	.054036	.195	.107842	.269	.170902
.048	.013818	.122	.054689	.196	.108636	.270	.171089
.049	.014247	.123	.055345	.197	.109430	.271	.171978
.050	.014681	.124	.056003	.198	.110226	.272	.172867
.051	.015119	.125	.056663	.199	.111024	.273	.173758
.052	.015561	.126	.057326	.200	.111823	.274	.174649
.053	.016007	.127	.057991	.201	.112624	.275	.175542
.054	.016457	.128	.058658	.202	.113426	.276	.176435
.055	.016911	.129	.059327	.203	.114230	.277	.177330
.056	.017369	.130	.059999	.204	.115035	.278	.178225
.057	.017831	.131	.060672	.205	.115842	.279	.179122
.058	.018296	.132	.061348	.206	.116650	.280	.180019
.059	.018766	.133	.062026	.207	.117460	.281	.180918
.060	.019239	.134	.062707	.208	.118271	.282	.181817
.061	.019716	.135	.063389	.209	.119083	.283	.182718
.062	.020196	.136	.064074	.210	.119897	.284	.183619
.063	.020680	.137	.064760	.211	.120712	.285	.184521
.064	.021168	.138	.065449	.212	.121529	.286	.185425
.065	.021659	.139	.066149	.213	.122347	.287	.186329
.066	.022154	.140	.066833	.214	.123167	.288	.187234
.067	.022652	.141	.067528	.215	.123988	.289	.188140
.068	.023154	.142	.068225	.216	.124810	.290	.189047
.069	.023659	.143	.068924	.217	.125634	.291	.189955
.070	.024168	.144	.069625	.218	.126459	.292	.190864
.071	.024680	.145	.070328	.219	.127285	.293	.191775
.072	.025195	.146	.071033	.220	.128113	.294	.192684
.073	.025714	.147	.071741	.221	.128942	.295	.193596
.074	.026236	.148	.072450	.222	.129773	.296	.194509

Table of Areas, &c.,—Continued.

Height.	Area Seg.	Height.	Area Seg.	Height.	Area Seg.	Height.	Area Seg.
.297	.195422	.348	.243074	.399	.292390	.450	.342782
.298	.196337	.349	.244026	.400	.293396	.451	.343777
.299	.197252	.350	.244980	.401	.294349	.452	344772
.300	.198168	.351	.245934	.402	.295330	.453	.345768
.301	.199085	.352	.246889	.403	.296311	.454	.346764
.302	.200003	.353	.247845	.404	.297292	.455	.347759
303	.200922	.354	.248801	.405	.298273	.456	.348755
.304	.201841	.355	.249757	.406	.299255	.457	.349752
.305	.202761	.356	.250715	.407	.300238	.458	.350748
.306	.203863	.357	.251673	.408	.301220	.459	.351745
.307	.204605	.358	.252631	.409	.202203	.460	.352741
.308	.205527	.359	.253590	.410	.303187	.461	.353789
.309	.206451	.360	.254550	.411	.304171	.462	.354736
.310	.207376	.361	.255510	.412	.305155	.463	.355732
.311	.208301	.362	.256471	.413	.306140	.464	.356730
.312	.209227	.363	.257433	.414	.307125	.465	.357727
.313	.210154	.364	.258395	.415	.308110	.466	.358725
.314	.211082	.365	.259357	.416	.309096	.467	.359723
.315	.212011	.366	.260320	.417	.310081	.468	.360721
.316	.212940	.367	.261284	.418	.311068	.469	.361719
.317	.213871	.368	.262248	.419	.312054	.470	.362717
.318	.214802	.369	.263213	.420	.313041	.471	.363715
.319	.215733	.370	.264178	.421	.314029	.472	.364713
.320	.216666	.371	.265144	.422	.315016	.473	.365712
.321	.217599	.372	.266111	.423	.316004	.474	.366710
.322	.218533	.373	.267078	.424	.316992	.475	.367709
.323	.219468	.374	.268048	.425	.317981	.476	.368708
.324	.220404	.375	.269013	.426	.318970	.477	.369707
.325	.221340	.376	.269982	.427	.319959	.478	.370706
.326	.222277	.377	.270951	.428	.320948	.479	.371705
.327	.223215	.378	.271920	.429	.321938	.480	.372704
.328	.224154	.379	.272890	.430	.322928	.481	.373703
.329	.225093	.380	.273816	.431	.323918	.482	.374702
.330	.226033	.381	.274832	.432	.324909	.483	.375702
.331	.226974	.382	.275803	.433	.325900	.484	.376702
.332	.227915	.383	.276775	.434	.326892	.485	.377701
.333	.228858	.384	.277748	.435	.327882	.486	.378701
.334	.229801	.385	.278721	.436	.328874	.487	.379700
.335	.230745	.386	.279694	.437	.329866	.488	.380700
.336	.231689	.387	.280668	.438	.330858	.489	.381699
.337	.232684	.388	.281642	.439	.331850	.490	.382699
.338	.233580	.389	.282617	.440	.332843	.491	.383699
.339	.234526	.390	.283592	.441	.333836	.492	.384699
.340	.235473	.391	.284568	.442	.334829	.493	.385699
.341	.236421	.392	.285544	.443	.335822	.494	.386699
.342	.237369	.393	.286521	.444	.336816	.495	.387699
.343	.238318	.394	.287498	.445	.337310	.496	.388699
.344	.239268	.395	.288476	.446	.338804	.497	.389699
.345	.240218	.396	.289453	.447	.339798	.498	.390699
346	.241169	.397	.290430	.448	.340793	.499	.391699
.347	.242121	.398	.291411	.449	.341787	.500	.392699

To find the Area of the Segment of a circle by the preceding Table.

Divide the height of the segment by the diameter of the circle, so that the quotient may contain three places of decimals; look for the corresponding number to the quotient in the column height, then take out the number in the same horizontal row in the vertical column, intitled *Area Seg.* at the top; multiply the square of the diameter by the number thus taken out, and the product will be the area of the segment.

Example.—Required the area of the segment of a circle, the height of which is two, and the diameter of the circle 52

52)2.000(.038
156

440
416

24

There remains 24, which is $\frac{24}{52} = \frac{6}{13}$.

The area of the segment corresponding to .038, is .009763, but since there is a fraction over and above .038 of $\frac{6}{13}$, find the next greater area .010148; take the difference betweer these two areas, which is .000385, multiply this difference by the fraction $\frac{6}{13}$, and it gives, .000177, which being added to .009763, gives .009940 for the area of the segment, answering to $.038\frac{6}{13}$.

The table is founded upon the following principle: Let the diameter of a circle be 1, which suppose divided into 1,000 equal parts, through every one of which imagine perpendiculars drawn and continued both ways to the circumference.

Then, since the versed sine is .001, we have $v = .001$ and $\frac{v}{\text{V}} = \frac{.001}{999} = \frac{.1}{999}$; therefore $\text{A} = \frac{4\,v}{3}\sqrt{v\,\text{V}} = \frac{4}{3000}\sqrt{.000999} = .00004214$, and $\text{B} = \frac{\text{A}\,v}{5\,\text{V}} = \frac{.00004215}{999 \times 5} = .00000001$, whence the first number of the table is .00004215.

The second versed sine is $.002 = v$, therefore $\text{V} = .998$ and $\frac{v}{\text{V}} = \frac{2}{998} = \frac{1}{199}$, whence $\text{A} = \frac{8}{3000}\sqrt{.001996} = .00011914$, and $\text{B} = \frac{\text{A}\,v}{5\,\text{V}} = \frac{.00011914}{499 \times 5} = .00000005$; therefore the second number is .00011919.

The third versed sine is $.003 = v$, therefore $\text{V} = 1 - .003 = .997$, whence $\frac{v}{\text{V}} = \frac{4}{997}$, and $\text{A} = \frac{12}{3000}\sqrt{.002991} = .00021876$: also $\text{B} = \frac{\text{A}\,v}{5\,\text{V}} = \frac{.00021876 \times 3}{5 \times 997} = .00000013$; thence the third number of the Table is .00021889.

And by this method the whole might be computed; but after a sufficient number of terms are found at the beginning of the table, the rest may be had (to seven or eight places of decimals) by this rule: let α, β, γ, δ, denote any four terms succeeding in the order of the letters, then $\delta = \alpha + \beta \times \gamma - \beta$.

And if any term of this Table be divided by 78539816, or multiplied by its reciprocal, it will produce the common table of segments, when the area is unity.

MERIDIAN, in astronomy, a great circle of the sphere, passing through the zenith, nadir, and poles of the world, crossing the equinoctial at right angles, and dividing the sphere into two hemispheres, the one eastern and the other western.

It is called meridian, from the Latin *meridies*, *noon*, or *mid-day*, because when the sun is in this circle, it is noon in all places situated under it.

MERIDIAN, in geography, a great circle, as PAQD, passing through the poles of the earth P and Q, and any given place at Z. So that the plane of the terrestrial meridian is in the plane of the celestial one.

Hence, 1. As the meridian invests the whole earth, there are several places situated under the same meridian. And, 2. As it is noon-tide whenever the centre of the sun is in the meridian of the heavens, and as the meridian of the earth is in the plane of the former, it follows, that it is noon at the same time, in all places situate under the same meridian. 3. There are as many meridians on the earth as there are points conceived in the equator. In effect, the meridians always change, as the longitude of the place is varied; and may be said to be infinite; each respective place, from east to west, having its respective meridian.

MERIDIAN, *First*, is that from which the rest are accounted, reckoning from west to east. The first meridian is the beginning of longitude.

The fixing of the first meridian is merely arbitrary; and hence different persons, nations, and ages, have fixed it differently; whence some confusion has arisen in geography. The rule among the ancients was, to make it pass through the place farthest to the west that was known. But the moderns, knowing that there is no such place in the earth as can be esteemed the most westerly, the way of computing the longitudes of places from one fixed point is much laid aside.

But without much regard to any of these rules, our geographers and map-makers frequently assume the meridian of the place where they live, or the capital of their country, for a first meridian; and thence reckon the longitudes of their places.

The astronomers, in their calculations, usually choose the meridian of the place where their observations are made, for their first meridian; as Ptolemy, at Alexandria; Tycho Brahe, at Uranibourg; Riccioli, at Bologna; Mr. Flamsteed, at the Royal Observatory at Greenwich; and the French, at the Observatory at Paris.

MERIDIAN LINE, an arc, or part of the meridian of the place, terminated each way by the horizon. Or, a meridian line is the intersection of the plane of the meridian of the place with the plane of the horizon, vulgarly called a *north and south line*, because its direction is from one pole towards the other.

The use of a meridian line in astronomy, geography, dialing, &c., is very great, and on its exactness all depends; whence infinite pains have been taken by divers astronomers to fix it with the utmost precision. M. Cassini has distinguished himself by a meridian line drawn on the pavement of the church of S. Petronio, at Bologna, the largest and most accurate in the world; being 120 feet in length. In the roof of this church, 1,000 inches above the pavement, is a little hole, through which the sun's rays, when in the meridian, falling upon the line, mark his progress all the year. When finished, M. Cassini, by a public writing, informed the mathematicians of Europe of a new oracle of Apollo, or the Sun established in a temple, which might be consulted, with entire confidence, as to all difficulties in astronomy.

To draw a meridian line.

On the horizontal plane, from the same centre, C, draw several arcs of circles, B A, *b a*, &c., and on the same centre, C, erect a style, or gnomon, perpendicular to the plane A C B, a foot, or half a foot long. About the 21st of June, between the hours of nine and eleven in the morning, and between one and three in the afternoon, observe the points B, *b*, &c., A, *a*, wherein the shadow of the style terminates. Bisect the arcs A B, *a b*, &c., in D, *d*, &c. If then the same right line, D E, bisect all the arcs, A B, *a b*, &c., it will be the meridian line sought.

As it is difficult to determine the extremity of the shadow exactly, it is best to have the style flat at top, and to drill a little hole, noting the lucid spot projected by it on the arcs A B and *a b*, instead of the extremity of the shadow. Otherwise the circles may be made with yellow, instead of black, &c.

If the meridian line be bisected by a right line, O V, drawn perpendicularly through the point C, O V will be the intersection of the meridian, and first vertical; and, consequently, O will show the east point, and V the west.

Lastly,—If a style be erected perpendicularly in any other horizontal plane, and a signal be given when the shadow of the style covers the meridian line drawn in another plane, noting the apex, or extremity, of the shadow projected by the style, a line drawn from that point through that wherein the style is raised, will be a meridian line.

MERIDIAN LINE, on a dial, is a right line arising from the intersection of the meridian of the place with the plane of the dial. This is the line of twelve o'clock, and from hence the division of the hour-line begins.

MERLON, the elevated or solid portion of a battlement which alternates with the embrasures.

MEROS, (Greek,) the middle part of the triglyph. The breadth of the triglyph is divided into six parts; of which five are placed in the middle, two and a half being on either side. The middle one makes the regula, or femur, which the Greeks call *meros*. On either side of this are the channels, sunk as if imprinted with the elbow of a square. To the right and left of these another femur is formed, and at the extremities semi-channels are slanted.

MESAULÆ, in Grecian architecture, passages between the peristylium and hospitalium; the same as the audionas of the Romans. *See* HOUSE.

META, the goal in the Roman circus to which the chariots ran.

METAGENAS, a Grecian architect, who wrote a description of the temple of Diana at Ephesus; he also jointly conducted this edifice with his father Ctesiphontes, the Gnossian.

METALS. *See* MATERIALS, IRON, &c.

METATOME, the interval between two dentals.

METEZAU, CLEMENT, a celebrated French architect, who flourished in the former part of the seventeenth century, was a native of Dreux, but settled at Paris, became architect to Louis XIII., and acquired much fame by carrying into execution, with Tiriot, a Parisian mason, the plan suggested by Cardinal Richelieu, for reducing Rochelle by means of an immense dyke, in imitation of what Cæsar had done at Durazzo, and Alexander the Great at Tyre. This scheme was to run a solid wall across a gulf upwards of 740 fathoms, or more than three-quarters of a mile broad, into which the sea rolled with great force, and, when the wind was high, with an impetuosity which seemed to set at defiance the art of man. Those who had undertaken the business were not to be turned aside by any obstacles: they began by throwing in huge rocks, to lay a kind of foundation; upon these were placed vast stones, cemented by the mud thrown up by the sea. These were supported by immense beams, driven into the bottom with incredible labour. It was raised so high that the soldiers were not incommoded by the water even at spring-tides. The platform was nearly 30 feet wide, and 90 feet at the foundation. At each extremity there was a strong fort, in the middle there was an open passage of 150 paces, several vessels being sunk immediately before it, together with high stakes in a double row, and before these thirty-five vessels linked together, so as to form a kind of floating palisade. This amazing dyke was completed in somewhat less than six months, and proved the principal means of occasioning the surrender of the city. So honourable were the exertions of M. Metezau in this business, that his portrait was circulated widely through France, to which were attached the following lines:

"Dicitur Archimedes Terram potuisse movere;
Æquora qui potuit sistere, non minor est."

METOCHE, (from the Greek μετοχε), in ancient architecture, a term used by Vitruvius, to signify the space or interval between the dentils of the Ionic, or triglyphs of the Doric orders.

Baldus observes, that, in an ancient MS. copy of that author

the word *metatome* is found for *metoche*. Hence Daviler takes occasion to suspect that the common text of Vitruvius is corrupted, and concludes that it should not be *metoche*, but *metatome*, q. d. *section*.

METOPE, or METOPA, (from μετα, *inter*, *between*, and οπη, *an aperture*), in architecture, the square piece or interval between the triglyphs, in the Doric frieze. In the original Greek the word signifies the distance between one aperture, or hole, and another, or between one triglyph and another; the triglyphs being supposed to be solives, or joists, that fill the apertures.

Vitruvius having shown that the Doric order took its rise from the disposition of the timberwork in the construction of the original hut, proceeds as follows:

"From this imitation, therefore, arose the use of triglyphs and mutules in Doric work: for it cannot be, as some erroneously assert, that the triglyphs represent windows; because triglyphs are disposed in the angles, and over the quarters of the columns, in which places windows are not permitted; for if windows were there left, the union of the angles of buildings would be dissolved; also, if the triglyphs are supposed to be situated in the place of the windows, by the same reason the dentils in Ionic work may be thought to occupy the places of the windows; for the intervals between the dentils, as well as between the triglyphs, are called *metopæ;* the Greeks calling the bed of the joists and assers *opas*, (as we call it *cava*, *columbaria;*) so because the inter-joist is between two opæ, it is by them called *met-opæ*."

As some difficulty arises in disposing the triglyphs and metopes in that just symmetry which the Doric order requires, many architects use this order only in temples.

In the Doric order, it is not the space between the mutules, but the space between the triglyphs, that forms the metope.

From the authority of Stewart, in his *Ruins of Athens*, the following proportions are taken; where observe, that feet are distinguished by the mark (′) being placed over them, and inches thus (″); the numbers following the latter are decimals.

In the Doric portico at Athens, the breadth of the metope, or space between the triglyphs, is 3′ 3″ and 3′ 3″.6, (*see* Chap. I. Plate IV.); the height is 3′ 0″.7, including the band or capital over it, (*see* Plate V.): or without the band, 2′ 9″.05, (*see* Plate VI).

In the temple of Minerva, at Athens, (Vol. ii. Chap. I.) the height of the metope, without its capital, or band, is 3′ 11″.15, (*see* Plate VI.); and the breadth of the metope is 4′ 3″.35.

In the Propylæa, (Vol. II. Chap. V. Plate VI.) the breadth of the metope is 3′ 8″.25, and the height 3′ 9″.85, including the band and the bead over it; and in the entablature of the ante (Plate IX.) the breadth of the metope is 2′ 8″.734, and the height 2′ 5″, without the band.

In the temple of Theseus, (Vol. III. Chap. I. Plate VI.) the breadth of the metope is 2′ 6″.475, and its height 2′ 8″.55, including a very broad band. So that the height of the tympan, or panel, is universally less than the breadth.

MEXICAN ARCHITECTURE, is remarkable chiefly as forming a specimen of the style and mode of building adopted by the aborigines of the New World. Their resemblance to some of the ancient edifices and forms of building prevalent in the eastern continent is curious, and worthy of comment. The only Mexican buildings of which we have any remains are the teocallis, or houses of God, which are almost universally of the pyramidal form, resembling the pyramids of Egypt, but bearing, it would seem, even a more striking similarity to the famous tower of Babel, as described by Herodotus and modern travellers. *See* BABYLONIAN ARCHITECTURE. This resemblance is especially pointed out by Humboldt, to whom we are indebted for the greater part of our information on the subject.

These teocallis were solid masses of earth raised up in a pyramidal form, having the shape of a truncated pyramid, and faced either entirely or partially with masonry. In the interior were small cavities similar to those discovered in the Egyptian pyramids, and which were evidently intended for places of sepulture. The sides of the pyramid often face the cardinal points, and are divided into steps or stories on the exterior, in both which particulars they resemble those of Egypt. Their similarity to the tower of Babel is noticed further in the temple at the top of the pyramid, and, the use to which both erections were put as observatories for astronomical purposes.

The largest temple in Mexico is the great pyramid of Cholula, which is constructed of alternate layers of unburnt bricks and clay, and consists of four stories. In the interior are cavities of considerable size, one of which, upon being laid open was found to contain skeletons and a number of curiously painted and varnished vases, thus proving their sepulchral character. The height of the pyramid is 177 feet, the length of a side of the base 1,423 feet, the area on the top 3,500 yards, and the number of steps to the top 120.

At Papantla, in the northern part of Vera Cruz, is a small pyramid, 80 feet square at the base and 60 feet high, divided into seven stories, and ascended by a flight of 57 steps. It is constructed of immense blocks of stone laid in mortar, the faces of which are covered with hieroglyphics, amongst which are to be seen serpents and crocodiles. There are also a number of niches regularly disposed round each story.

A mass of ruins known as the Casa Grande are situated in the gulph of California, on the banks of the Rio Gila: the sides facing the cardinal points are of irregular size, those from north to south measuring 445 feet, while those from east to west are only 276 feet. They are composed of unburnt bricks of irregular size, the walls being 4 feet in thickness, and divided into three stories.

"In the district of Oaxaca, south of Mexico, stands the palace of Mitla, contracted from Mignitlan, signifying, in Aztec, the *place of woe*. By the Tzapotec Indians the ruins are called *leoba* or *luiva* (burial or tomb), alluding to the excavations found beneath the walls. It is conjectured to have been a palace constructed over the tombs of the kings, for retirement, on the death of a relation. The tombs of Mitla are three edifices, placed symmetrically in a very romantic situation. That in the best preservation, and, at the same time the principal one, is nearly 130 feet long. A staircase formed in a pit, leads to a subterranean apartment 88 feet in length and twenty-six in width. This, as well as the exterior part of the edifice, is decorated with fret and other ornaments of similar character. But the most singular feature in these ruins, as compared with other Mexican architecture, was the discovery of six porphyry columns, placed for the support of a ceiling in the midst of a vast hall. They are almost the only ones which have been found in the new continent, and exhibit strong marks of the infancy of the art, having neither base nor capital. The upper part slightly diminishes. Their total height is 19 feet in single blocks of porphyry. The ceiling under which they were placed was formed by beams of sabine wood, and three of them are still in good preservation. The roof is of very large slabs. The number of separate buildings was originally five, and they were disposed with great regularity. The gate, whereof some vestiges are still discernible, led to a court 150 feet square, which, from the rubbish and remains of subterranean apartments, it is

supposed was surrounded by four oblong edifices. That on the right is tolerably preserved, the remains of two columns being still in existence. The principal building had a terrace, raised between three and four feet above the level of the court, and serving as a base to the walls it surrounds. In the wall is a niche with pillars four or five feet above the level of the floor. The stone lintel over the principal door of the hall is in a single block 12 feet long and 3 feet deep. The excavation is reached by a very wide staircase, and is in the form of a cross, supported by columns. The two portions of it which intersect each other at right angles are each 82 feet long by 25 feet wide. The inner court is surrounded by three small apartments having no communication with the fourth, which is behind the niche. The interiors of these apartments are decorated with paintings of weapons, feathers, and trophies. Of windows there are no traces. Humboldt was struck with the resemblance of some of the ornaments to those on Etruscan vases of Lower Italy. In the neighbourhood of these ruins are the remains of a large pyramid and other buildings."

The only remarkable monuments in the valley of Mexico, Mr. Humboldt tells us, are the remains of the two pyramids of San Juan de Teotihuacan, on the north-east of the lake Tezcuco, consecrated to the sun and moon, and called by the Indians Tonatiuh Ytzaqual, (house of the sun,) and Metzli Ytzaqual, (house of the moon.) Mr. Bullock visited this site on his return from Themasceltepec. For some time before he reaches the gate of Tezcuco, the traveller is apprised of his approach to a place of ancient importance by a large aqueduct still in use, and the ruins of several stone buildings. The Spanish quarters, built for Cortes, are still entire. Several tumuli are seen on entering the gates, which are supposed to have been teocallis. The most important ruin is what Mr. Bullock calls the site of the palace of the ancient caziques of Tezcuco, which, though in ruins, far surpassed every idea he had formed of ancient Mexican architecture. It extended 300 feet, forming one side of the great square, and was placed on sloping terraces, raised one above another by small steps. Some of these terraces are still entire, and are covered with cement, very hard, and equal in beauty to that found in ancient Roman buildings. From what is known of the extensive foundations of this palace, it must have occupied some acres of ground. It was composed of large blocks of basaltic stone, of about 4 or 5 feet long and $2\frac{1}{2}$ or 3 feet thick, cut and polished with the utmost exactness. The sculptured stones from these ruins have been used in building the modern churches and houses. Heaps of ruins surround it on every side, and Tezcuco, the Athens of Anahuac, as it is called by a Spanish historian, would seem to invite, above all others in Mexico, the attention of the antiquary.

At about two leagues from Tezcuco, is a spot called Bano de Montezuma, Montezuma's Bath, on the summit of a conical hill called Tescosingo. "We scrambled with great difficulty," observes Mr. Bullock, "through bushes and over loose stones, which were in great quantities on all sides, and at last perceived that we were on the ruins of a very large building, the cemented stones remaining in some places covered with stucco, and forming walks and terraces, but much encumbered with earth fallen from above, and overgrown with a wood of nopal, which made it difficult to ascend." He discovered the bath on one of the sides of the hill. "It was cut in the solid rock, and standing out like a martin's nest from the side of a house. It is not only an extraordinary bath, but still more extraordinarily placed. It is a beautiful basin, about 12 feet long by 8 wide, having a well about 5 feet by 4 deep in the centre, surrounded by a parapet or ruin 2 feet 6 inches high, with a throne or chair such as is represented in ancient pictures to have been used by the kings. There are steps to descend into the basin or bath, the whole cut out of living porphyry rock, with the utmost mathematical precision, and polished in the most beautiful manner." The mountains appear to have been covered with palaces, temples, baths, hanging gardens, &c.; and Mr. Bullock was informed that he had seen but the commencement of the wonders of the place.

About two miles from Tezcuco, is the Indian village of Huexotla. Mr. Bullock observed, on his approach, several small pyramids of alternate layers of clay and unburnt brick, one of them had evidently an entrance in the centre, which was discovered by part of it having fallen in; within the town were the foundations of a palace, and two large reservoirs, with which it was supplied with water, remain entire. The ancient wall of the town, almost 30 feet high and very thick, extends to a considerable distance. It is singularly constructed, being divided into five unequal parts. The broadest division is built of large oval stones, with ends standing out, so as to give it the appearance of having been formed of human sculls, and it is divided from the rest by a projecting cornice. Beyond the walls, on the road to Tezcuco, a broad covered-way runs between two huge walls terminating near a river, which appears to have been one of the entrances to the town. Over the bed of the river, which is now dry, there is a remarkable bridge, with a pointed arch nearly 40 feet high, supported on one side by a mass of masonry in a pyramidal shape. It is ascribed to the ancient Mexicans; but if constructed on the principle of the arch, it must have been the work of European architects.

Mr. Bullock visited the celebrated pyramids of San Juan di Teotihuacan. "As we approached them," he says, "the square and perfect form of the largest became at every step more and more visibly distinct, and the terraces could now be counted. We rode first to the lesser, which is the most dilapidated of the two, and ascended to the top, over masses of fallen stone and ruins of masonry, with less difficulty than we expected. On the summit are the remains of an ancient building, 47 feet long and 14 wide; the walls are composed of unhewn stone, 3 feet thick and 8 feet high, with entrances at the south end, with three windows on each side, and on the north end it appears to have been divided at about one third of its length; we soon arrived at the foot of the largest pyramid, and began to ascend. It was less difficult than we expected, though, the whole way up, lime and cement are mixed with fallen stones. The terraces are perfectly visible, particularly the second, which is about 38 feet wide, covered with a coat of red cement 8 or 10 inches thick, composed of small pebble-stones and lime. In many places as you ascend, the nopal trees have destroyed the regularity of the steps, but nowhere injured the general figure of the square, which is as perfect in this respect as the great pyramid of Egypt. We everywhere observed broken pieces of instruments like knives, arrows, spear-heads, &c., of obsidian, the same as those found on the small hills of Cholula; and on reaching the summit, we found a flat surface of considerable size, but which has been much broken and disturbed. On it was probably a temple or some other building; report says, a statue covered with gold. We rested some time on the summit, enjoying one of the finest prospects imaginable, in which the city of Mexico is included. Here I found fragments of small statues and earthenware, and what surprised me more, oyster-shells, the first I had seen in Mexico. In descending, I also found some ornamental pieces of earthenware. The pattern, one of which is in relief, much resembling those of China, the other has a grotesque human face. On the north-east side, about half way down, at some remote period an

opening has been attempted. This should have been from the south to the north, and on a level with the ground, or only a few feet above it, as all the remains of similar buildings have been found to have their entrances in that direction. According to the measurements made by Dr. Oteyza, a young Mexican savant, in 1803, the base of the larger pyramid is 682 feet long, and its elevation 180 feet perpendicular; Mr. Bullock thinks its height to be nearly half the base. The other pyramid, that of the moon, is 36 feet lower, and its base much smaller. They are constructed of clay mixed with small stones, covered with a thick facing of porous amygdaloid, over which was a coating of cement. There are four stages subdivided into smaller steps; a stair of hewn stone formerly led to their summits. Early travellers all mention the prevailing tradition, that their interior was hollow. Around them in the plain, there are several hundred smaller ones, in general about 30 feet high; which, according to the tradition, were dedicated to the stars. It is probable, however, that the whole plain was a vast burial-place, its Aztec name was Micaotl, the road of the dead; which the Spaniards, borrowing a word from the language of the island of Cuba, have rendered Llano de los Cues. They are supposed to be the most ancient of all the Mexican monuments."

MEZANINE, or MEZZANINE, a word borrowed from the Italians, who call *mezzanini* those little windows, less in height than breadth, which serve to illuminate an attic, or entresole. It is used by some architects, to signify an intermediate apartment, frequently introduced into the principal story when all the rooms are not required to be of the same height; so that where mezanines are introduced, the principal story is divided into two heights, in order to make store-rooms, or lodging-rooms for servants. *See* APARTMENT.

MEZZO-RELIEVO, a piece of sculpture in half relief. *See* BAS-RELIEF.

MIDDLE-POST, in a roof, the same as KING-POST; which see.

MIDDLE-QUARTERS OF COLUMNS. When the plan or horizontal section of a column is divided into four quadrants, by lines not at right angles to the front, but at an angle of 45 degrees therewith, the four quarters are called the *middle quarters*.

MILE (from the Latin, *mille*, a thousand) a long measure, whereby the English, Italians, and some other nations, express the distance between places. *See* MEASURE.

In this sense *mile* is used to the same purpose with league, by the French and other nations. The mile is of various extent in different countries. The geographical, or Italian mile, contains a thousand geometrical paces, *mille passus*, whence the term *mile* is derived.

The English mile consists of eight furlongs, each furlong of 40 poles, and each pole of $16\frac{1}{2}$ feet: so that it is equal to 1760 yards, or 5280 feet.

The mile employed by the Romans in Great Britain, and restored by Henry VII., is our present English mile. A degree of the meridian in England, north latitude 52, according to the measurement of Colonel Mudge, is 121,640 yards, or 69.114 miles. A geographical, or sea-mile, is the 60th part of such a degree, *i. e.* $2{,}027\frac{1}{3}$ yards; and three sea-miles make a league. A degree of the meridian, in north latitude 45, as measured in France in 1796, is 57,008 toises = 121,512 yards = 69.092 English miles.

Casimir has made a curious reduction of the miles, or leagues, of the several countries in Europe into Roman feet, which are equal to the Rhinland feet generally used throughout the north.

	Feet.
The mile of Italy	50,000
" of England	5,454
" of Scotland	6,000
" of Sweden	30,000
" of Muscovy	3,750
" of Lithuania	18,500
" of Poland	19,850
" of Germany, the small	20,000
" " the middle	22,500
" " the largest	25,000
" of France	15,750
" of Spain	21,270
" of Burgundy	18,000
" of Flanders	20,000
" of Holland	24,000
" of Persia, called also *parasanga*	18,750
" of Egypt, called also *schœnos*	25,000

A Table of the Length of Miles, Leagues, &c. ancient and modern, in English yards.

	Eng. Yards.
Ancient Roman mile	1610.348
Olympic stadium = $\frac{1}{8}$th of an ancient Roman mile	201.2935
Stadium = $\frac{1}{10}$th of an ancient Roman mile	161.0348
Stadium = 1100th part of a degree	111.2
Jewish risin, of which $7\frac{1}{2}$ = an ancient Roman mile	214.713
Gallic leuca = $1\frac{1}{2}$ ancient Roman mile	2415.522
German rast, or common league in France = 2 Gallic leuca	4831.044
Persian parasanga = 2 Gallic leagues	4831.044
Egyptian schœnos = 4 ancient Roman miles	6441.392
German league, or that of Scandinavia = 2 rasts	9662.088
The mile, or league of Germany = 200 Rhenish yards	8239.846
Great Arabian mile, used in Palestine in the time of the Crusades, rated at $1\frac{1}{2}$ ancient Roman mile	2415.713
Modern Roman mile	1628.466
Modern Greek mile of 7 Olympic stadia	1409.0545
Modern French league = 2,500 toises	5328.75
Mile of Turkey, and the common werst of Russia, supposing it seven Olympic stadia	1409.0545
League of Spain = 4 ancient Roman miles	6441.392
Large league of Spain = 5 ditto	8051.74

MILITARY ARCHITECTURE, denotes the art of fortification. *See* ARCHITECTURE.

MILLSTONE-GRIT, a coarse-grained quartzy sandstone. It is found between the mountain-limestone and the superincumbent coal formations.

MILK-HOUSE, or ROOM, an apartment for keeping milk sweet and good; this apartment ought to be as cool as possible, and on no account exposed to the rays of the sun; consequently a northern situation, when it can be obtained, will be the most eligible for this purpose. *See* DAIRY.

MINARET, or MINNERET, a Turkish steeple with a balcony, from which a person calls the people to prayers; no bells being permitted in Turkey.

MINION, an iron ore, useful in the composition of mortar; when mixed with a proper quantity of lime, it makes an excellent water-cement. *See* CEMENT and MORTAR.

MINOTAUR, or MINOTAURUS, a fabulous monster much talked of by the poets; feigned to be half a man and half a bull.

MINSTER, the church belonging to a monastery.

MINSTREL GALLERY, a gallery in old halls, in which the minstrels sat during the feast. There is a gallery so termed near the centre of the choir of Exeter cathedral.

MINUTE, (from the Latin, *minutus*, small) in architecture, usually denotes the sixtieth, but sometimes only the thirtieth, part or division of a module.

MISERERE, a term applied to a seat of peculiar form, found in some of our larger churches and cathedrals. It is in shape like a bracket, and turns up on a hinge. When down, it forms a seat of the usual height and size, and the front beneath the seat is usually carved into a knop of foliage, or otherwise; but when turned up, this front presents a small high seat, which was used to recline against. It falls back out of the perpendicular, so as to retain itself in its position, but will fall forward with the least motion of the occupant.

MITCHELS, among builders, are Purbeck stones, from 15 inches square to 2 feet, squared and hewed ready for building.

MITRE, or MITRA, (from Μιτρα, a head-dress) a pontifical ornament, worn on the head by bishops, and certain abbots, on solemn occasions.

The mitre is a round cap, pointed, and cleft at top, with pendants hanging down on the shoulders, and fringed at both ends. The bishop's is only surrounded with a fillet of gold, set with precious stones; the archbishop's issues out of a ducal coronet. These are never used otherwise than on their coats of arms. Abbots wear the mitre turned in profile, and bear the crosier inwards, to show that they have no spiritual jurisdiction without their own cloisters.

The pope has also granted to some canons of cathedrals the privilege of wearing the mitre. The counts of Lyons are also said to have assisted at church in mitres.

MITRE, in joinery: when two pieces of wood contain equal angles, and one side of the one piece is joined to one side of the other, so that their vertices may coincide, the common seam, or joint, is called a *mitre*, and the pieces themselves are said to be *mitred*.

The whole angle thus joined is generally a right angle, and when this is the case, each of the pieces joined will be forty-five degrees.

Mitering is also employed in dovetail joints, in order to conceal the dovetailing.

MITRE-BOX, a trough for cutting mitres, having three sides, open at the ends.

MIXED ANGLE, an angle of which one side is a curve, and the other a straight line.

MIXED FIGURE, one that is composed of straight lines and curves, being neither entirely the sector nor the segment of a circle; nor the sector or segment of an ellipsis; nor a parabola nor an hyperbola.

MOAT, (from the Latin, *mota*, a ditch) in fortification, a deep trench dug round a town, or fortress, to be defended on the outside of the wall or rampart.

The depth and breadth of a moat often depend on the nature of the soil; according as it is marshy, rocky, or the like. The brink of the moat next the rampart, in any fortification, is called the *scarp*, and the opposite one the *counter-scarp*.

MODEL, (from the Latin, *modulus*, a copy) an original, or pattern, proposed for any one to copy or imitate. St. Paul's cathedral is said to be built after the model of St. Peter's at Rome.

MODEL is particularly used, in building, for an artificial pattern, made of wood, stone, plaster, or other matter, with all its parts and proportions; for the better guidance of the artificers in executing some great work, and to give an idea of the effect it will have when complete.

In all great buildings it is much the surest way to make a model in relievo; and not to trust to a bare design, or draught. There are also models for the building of ships &c., and for extraordinary staircases, &c.

MODEL, in painting and sculpture, anything proposed to be imitated.

Hence, in the academies, they give the term *model* to a naked man, disposed in several postures, to afford an opportunity to the scholars of designing him in various views and attitudes.

The sculptors have little models of clay, or wax, to assist them in their design of others that are larger, in marble, &c., and to judge of the attitude and correctness of a figure.

Statuaries likewise give the name *model* to certain figures of clay, or wax, which are but just fashioned, to serve by way of guide in the making of larger, whether of marble or other matter.

MODILLIONS, (French,) in architecture, mutules carved into consoles, placed under the soffit or bottom of the drip of the corona in the Corinthian and Roman orders, for supporting the larmier and sima, or appearing to perform the office of support.

In Grecian architecture, the Ionic order is without modillions in the cornice, as are also the Roman examples of the same order, except the temple of Concord, at Rome, which has both dentils and modillions.

A singular and curious example of a modillion cornice, but contrary to the principles of architecture, is to be found in the interior cornices of the Tower of the Winds, at Athens, in which the projecting part is much thicker than the interior, where the stress seems to lie, and, consequently, gives the idea of weakness.

A singular example of modillions is to be found in the frontispiece of Nero, at Rome, where they consist of two plain faces, separated by a small sima-reversa, and crowned with an ovolo and bead. Another very extraordinary form of modillions is that placed in the frieze of the fourth order of the Coliseum, cut on the outside, or projecting part, of a sima-reversa form.

In most examples of the Corinthian and Roman orders, the cornices have both dentils and modillions; but, if the two are used together, in good proportion to the other parts, so as to appear distinctly at a reasonable distance, the cornice will be overcharged, both in proportion and weight, to the other principal members of the entablature, or the entablature to the whole order; the one or the other ought, therefore, to be omitted in the same cornice.

In the general disposition of modillions, if each one is conceived to be divided into two equal parts by a vertical plane at right angles to the surface of the frieze, one of the modillions is so disposed, that its dividing vertical surface will be entirely in a plane passing through the axis of the column, and in the column next the angle of the building there is generally only one modillion between that through which the plane along the axis passes, and the angle of the cornice.

The vertical sides of modillions at right angles to the face, are generally finished with volutes of different sizes, and turned on different sides of the same line; the greater being that next to the vertical surface, to which they are attached, and the lesser at the extremity.

The soffits of the modillions, so constructed, follow the under line of the volutes, and the connecting undulated line which joins them. The upper part of each volute is on the same level, and is attached to a moulding of the sima-inversa form, which returns round it; and this moulding is again attached to the corona, which hangs over the modillion.

In some of the Roman buildings, the modillions are not placed over the axes of the columns, neither upon those at

the extremes, or over the axes of the intermediate shafts. In the Pantheon, the modillion next each angle of the building has its vertical side, which is opposed to the next modillion, nearer to the central plane of the portico, over the axis of the column, and consequently the whole breadth of the modillion on one side of the axis entirely, and on that side next to the angle of the building. In the whole portico are 47 modillions, including those at each extreme; the intervals are, therefore, 46 in number, and 44 between the columns that are between their axis. The portico is octostyle, and, consequently, the intercolumns are seven in number: from this it will be found, that if the columns were placed equidistantly, the number of intermodillions would be $6\frac{2}{7}$ in number. In this temple the corresponding intervals are very irregular. The two extreme ones are, according to Desgodetz, 9′ $4\frac{1}{4}$″, and 9′ $2\frac{3}{4}$″; the next two, nearer the centre, are 9′ $5\frac{1}{6}$″, and 9′ $1\frac{7}{8}$″; the next two, still nearer to the centre, are exactly equal, being 9′ 5″ each; and the central intercolumniation is 10′ $4\frac{3}{4}$″: so that the modillions appear to be equally divided, without any regard to the axis of the columns. The same irregularity in the disposition of the modillions may be observed in the temple of Concord, and in that of Jupiter the Thunderer. In the three remaining columns of the temple of Jupiter Stator, each column has a modillion placed over its axis, and each intercolumn has three modillions regularly disposed: the distance between the lower ends of the shafts are 3 modules, $4\frac{1}{2}$ parts, and the columns are in height 20 modules, $6\frac{5}{6}$ parts.

In the Pantheon, the modillions are placed in the pediment, contrary to the authority of Vitruvius.

MODULAR PROPORTION, that which is regulated by a module. *See* Module.

MODULATION, (from the Latin, *modulor*, to regulate,) the proportion of the parts of an order.

MODULE, (from the Latin, *modulus*, a pattern,) in architecture, a certain measure taken at pleasure, for regulating the proportions of columns, and the symmetry or distribution of the whole building.

Architects usually choose the diameter, or semi-diameter, of the bottom of the column, for their module; and this they subdivide into parts or minutes.

Vignola divides his module, which is a semi-diameter, into twelve parts, for the Tuscan and Doric; and into eighteen, for the other orders.

The module of Palladio, Scammozzi, M. Cambray, Desgodetz, Le Clerc, &c., which is also the semi-diameter, is divided into 30 parts or minutes, in all the orders.

Some divide the whole height of the column into 20 parts for the Doric, $22\frac{1}{2}$ for the Ionic, 25 for the Roman, &c., and one of these parts they make a module, by which to regulate the rest of the building.

There are two ways of determining the measures, or proportions of buildings: the first by a fixed standard measure, which is usually the diameter of the lower part of the column, called a *module*, subdivided into 60 parts, called *minutes*. In the second there are no minutes, nor any certain and stated division of the module; but it is divided occasionally into as many parts as are judged necessary. Thus the height of the Attic base, which is half the module, is divided either into three, to have the height of the plinth; or into four, for that of the greater torus; or into six, for that of the lesser.

Both these manners have been practised by the ancient as well as the modern architects; but the second, which was that chiefly used among the ancients, is, in the opinion of Perrault, preferable.

As Vitruvius, in the Doric order, has lessened his module, which, in the other orders, is the diameter of the lower part of the column, and has reduced that great module to a mean one, which is a semi-diameter; M. Perrault reduces the module to a third part, for the same reason, viz., to determine the several measures without a fraction. For in the Doric order, beside that the height of the base, as in the other orders, is determined by one of these mean modules; the same module gives likewise the heights of the capital, architrave, triglyphs, and metopes. But our little module, taken from the third of the diameter of the lower part of the column, has uses much more extensive; for, by this, the heights of pedestals of columns, and entablatures, in all orders, are determined without a fraction.

As then the great module, or diameter of the column, has 60 minutes; and the mean module, or half the diameter 30 minutes; our little module has 20. *See* Column.

MOILON, a name given by the French to a kind of stone, that forms the upper crust, and lies round the free-stone, in most quarries. It is an excellent substance for forming the body of fluxes, or soft enamel.

MOINEAU, (French,) in fortification, a flat bastion raised before a curtain when it is too long, and the bastions of the angles too remote to be able to defend each other.

Sometimes the moineau is joined to the curtain, and sometimes it is divided from it by a moat. Here musqueteers are placed, to fire each way.

MOLDING. *See* Moulding.

MOLE, (from the Latin, *moles*,) a massive work of large stones laid in the sea by means of coffer-dams, extending either in a right line, or in the arc of a circle, before a port, which it serves to close, to defend the vessels in it from the impetuosity of the waves, and to prevent the passage of ships without leave.

Mole is sometimes also used to signify the harbour itself.

Mole, among the Romans, was also used for a kind of mausoleum, built in the manner of a round tower on a square base, insulated, encompassed with columns, and covered with a dome.

The mole of the emperor Adrian, now the castle of St. Angelo, was the greatest and most stately of all the moles. It was crowned with a brazen pine-apple, in which was a golden urn containing the ashes of the emperor.

MOMENT or Momentum, (from the Latin,) the impetus, force, or quantity of motion in a moving body, or the word is sometimes used simply for the motion itself. Moment is frequently defined by the *vis insita*, or power by which moving bodies continually change place. In comparing the motion of bodies, the ratio of their momenta is always compounded of the quantity of matter, and the celerity of the moving body; so that the moment of any such body may be considered as a rectangle under the quantity of matter, and the celerity.

And since it is certain, that all equal rectangles have their sides reciprocally proportionable; therefore, if the momenta of any moving bodies be equal, the quantity of matter in one to that of the other, will be reciprocally as the celerity of the latter to that of the former; and, on the contrary, if the quantities of matter be reciprocally proportionable to the celerities, the momenta or quantities in each will be equal.

The moment, also, of any moving body may be considered as the aggregate or sum of all the momenta of the parts of that body; and, therefore, where the magnitudes and number of particles are the same, and where they are moved with the same celerity, there will be the same momenta of the whole. *See* Force.

MONASTERY, a convent, or house, built for the reception of religious devotees; whether it be abbey, priory, nunnery, or the like. The term is only properly applied to the

houses of monks, friars, and nuns. The rest are more properly called *religious houses*. *See* ABBEY.

The houses belonging to the several religious orders, which obtained in England and Wales, were cathedrals, colleges, abbeys, priories, preceptories, commanderies, hospitals, friaries, hermitages, chantries, and free chapels. These were under the direction and management of several officers. The dissolution of houses of this kind began so early as the year 1312, when the Templars were suppressed; and in 1323, their lands, churches, advowsons, and liberties, here in England, were given, by 17 Edw. II. stat. 3, to the priory and brethren of the hospital of St. John of Jerusalem. In the years 1390, 1437, 1441, 1459, 1497, 1505, 1508, and 1515, several other houses were dissolved, and their revenues settled on different colleges in Oxford and Cambridge. Soon after the last period, Cardinal Wolsey, by license of the king and pope, obtained a dissolution of above thirty religious houses, for the founding and endowing his colleges at Oxford and Ipswich. About the same time, a bull was granted by the same pope to Cardinal Wolsey, to suppress monasteries, where there were not above six monks, to the value of 8,000 ducats a year, for endowing Windsor, and King's College, in Cambridge; and two other bulls were granted to Cardinals Wolsey and Campeius, where there were less than twelve monks, and to annex them to the greater monasteries; and another bull to the same cardinals, to inquire about abbeys to be suppressed, in order to be made cathedrals. Although nothing appears to have been done in consequence of these bulls, the motive which induced Wolsey, and many others, to suppress these houses, was the desire of promoting learning; and Archbishop Cranmer engaged in it with a view of carrying on the Reformation. There were other causes that concurred to bring on their ruin: many of the devotees were loose and vicious; the monks were generally thought to be, in their hearts, attached to the pope's supremacy; their revenues were not employed according to the intent of the donors; many cheats in images, feigned miracles, and counterfeit relics, had been discovered, which brought the monks into disgrace; the Observant friars had opposed the king's divorce from Queen Catharine; and these circumstances operated, in concurrence with the king's want of a large supply, and the people's desire to save their money, to forward a motion in parliament, that, in order to support the king's state, and supply his wants, all the religious houses might be conferred upon the crown, which were not able to spend above £200 a year; and an act was passed for that purpose, 27 Hen. VIII. c. 28. By this about 380 houses were dissolved, and a revenue of £30,000 or £32,000 a year came to the crown; besides about £100,000 in plate and jewels. The suppression of these houses occasioned great discontent, and at length an open rebellion: when this was appeased, the king resolved to suppress the rest of the monasteries, and appointed a new visitation; which caused the greater abbeys to be surrendered apace; and it was enacted by 31 Hen. VIII. c. 13, that all monasteries, which have been surrendered since the 4th of February, in the twenty-seventh year of his majesty's reign, and which hereafter shall be surrendered, shall be vested in the king. The knights of St. John of Jerusalem were also suppressed by the 32 Henry VIII., c. 24. The suppression of these greater houses by these two acts, produced a revenue to the king of above £100,000 a year, besides a large sum in plate and jewels. The last act of dissolution, in this king's reign, was the act of 37 Hen. VIII., c. 4, for dissolving colleges, free chapels, chantries, &c., which act was farther enforced by 1 Ed. VI., c. 14. By this act were suppressed 90 colleges, 110 hospitals, and 2,374 chantries and free chapels. The number of houses and places suppressed, from first to last, so far as any calculations appear to have been made, seems to be as follows:

Of lesser monasteries, of which we have the valuation	374
Of greater monasteries	186
Belonging to the hospitallers	48
Colleges	90
Hospitals	110
Chantries and free chapels	2374
Total	3182

Besides the friars' houses, and those suppressed by Wolsey, and many small houses, of which we have no particular account.

The sum total of the clear yearly revenue of the several houses, at the time of their dissolution, of which we have any account, seems to be as follows:

	£.	s.	d.
Of the greater monasteries	104,919	13	3½
Of all those of the lesser monasteries, of which we have the valuation	29,702	1	10½
Knights hospitallers' head house in London	2,385	12	8
We have the valuation of only twenty-eight of their houses in the country	3,026	9	5
Friars' houses, of which we have the valuation	751	2	0¾
Total	140,784	19	3¾

If proper allowances are made for the lesser monasteries, and houses not included in this estimate, and for the plate, &c., which came into the hands of the king by the dissolution, and for the value of money at that time, which was at least six times as much as at present, and we also consider that the estimate of the lands was generally supposed to be much under the real worth, we must conclude their whole revenues to have been immense.

It doth not appear that any computation hath been made of the number of persons contained in the religious houses.

Those of the lesser monasteries dissolved by 27 Hen. VIII. were reckoned at about	10,000
If we suppose the colleges and hospitals to have contained a proportionable number, these will make about	5,347
If we reckon the number in the greater monasteries, according to the proportion of their revenues, they will be about 35,000; but as probably they had larger allowances in proportion to their number than those of the lesser monasteries, if we abate upon that account 5,000, they will then be	30,000
One for each chantry and free chapel	2,374
Total	47,721

But as there were probably more than one person to officiate in several of the free chapels, and there were other houses which are not included within this calculation, perhaps they may be computed in one general estimate at about 50,000. As there were pensions paid to almost all those of the greater monasteries, the king did not immediately come into the full enjoyment of their whole revenues: however, by means of what he did receive, he founded six new bishoprics, viz., those of Westminster, (which was changed by Queen Elizabeth into a deanery, with twelve prebends and a school,) Peterborough, Chester, Gloucester, Bristol, and Oxford. And in eight other sees he founded deaneries and chapters.

by converting the friars and monks into deans and prebendaries, viz., Canterbury, Winchester, Durham, Worcester, Rochester, Norwich, Ely, and Carlisle. He founded also the colleges of Christ-Church in Oxford, and Trinity in Cambridge, and finished King's College Chapel there. He likewise founded professorships of divinity, law, physic, and of the Hebrew and Greek tongues, in both the said universities. He gave the house of Gray Friars, and St. Bartholomew's Hospital, to the City of London; and a perpetual pension to the poor knights of Windsor; and laid out great sums in building and fortifying many ports in the Channel. It is observable, upon the whole, that the dissolution of their houses was an act, not of the church, but of the state, in the period preceding the Reformation, by a king and parliament of the Roman Catholic communion in all points except the king's supremacy; to which the pope himself, by his bulls and licenses, had led the way.

Although few will now be found entirely to approve either the original establishment or continued subsistence of monasteries, yet the destruction of them was felt and lamented, for a considerable time, as a great evil; and with good reason. One inconvenience that attended their dissolution was the loss of many valuable books, which their several libraries contained: for, during the middle ages, religious houses were the repositories of literature and science. Besides, they were schools of education and learning; for every convent had one person or more appointed for this purpose; and all the neighbours that desired it, might have their children taught grammar and church music there, without any expense. In the nunneries also, young females were taught to work and read; and not only people of the lower rank, but most of the noblemen's and gentlemen's daughters, were instructed in those places. All the monasteries were also in effect great hospitals, and were most of them obliged to relieve many poor people every day. They were likewise houses of entertainment for all travellers. And the nobility and gentry provided not only for their old servants in these houses, by corrodies, but for their younger children, and impoverished friends, by making them first monks and nuns, and in time priors and prioresses, abbots and abbesses. On the other hand, they were very injurious to the secular and parochial clergy, by taking on themselves many prebends and benefices, by getting many churches appropriated to them, and pensions out of many others; and by the exemptions they got from the episcopal jurisdiction, and from the payment of tithes. We say nothing now of the laxity of discipline, and acts of moral turpitude, which have been attributed to the inmates of such establishments; which, however greatly they have been exaggerated, did unquestionably prevail in some instances. Such faults, however, are chargeable rather upon individuals, than upon the system, against which the previous objections are of greater weight.

MONKEY, the weight used in pile-driving, which is raised to the top of the machine, and then allowed to fall on the head of the pile.

MONOGRAM, (Greek *εν μονω γραφειν*,) the combination or interlacing of several letters, so as to produce a single cipher or device, employed for the purpose of abbreviation.

MONOLITH, (*μονος*, *single*, and *λιθος*, *a stone*,) a structure consisting of a single colossal stone. The term is applied to such structures found in Celtic remains. *See* CELTIC ARCHITECTURE.

MONOPTERON, or MONOPTRAL TEMPLE (from *μονος*, *single*, and *πτερον*, *a wing*) in architecture, an edifice, consisting of a circular colonnade supporting a dome, without any enclosing wall, and consequently without a cell, as in other temples.

MONOTRIGLYPH, (from *μονος*, *single*, and *τριγλυφος*, *a triglyph*) having only one triglyph between two adjoining columns. The monotriglyph intercolumniation was the general practice in the Grecian Doric; as in the temple of Theseus, and in that of Minerva, at Athens.

Mr. Rively, in his preface to the third volume of Stewart's *Athens*, says, "There is a certain appearance of eternal duration in this species of edifice (meaning a Grecian Doric temple) that gives a solemn and majestic feeling, while every part is perceived to contribute its share to this character of durability. From this rapid sketch, it will readily be seen that no other intercolumniation than that of the monotriglyph can succeed in this dignified order. The Propylæa, indeed, as well as the temple of Augustus, or Agora, has one interval of the space of two triglyphs; but it is easy to perceive, that this deviation from the general principle was merely an accommodation to circumstances; both these buildings requiring a wide opening in the middle of the front. Accordingly, these are the only instances of this deviation to be found at Athens."

In the island of Delos, the portico of Philip, king of Macedon, is another instance.

MONSTRANCE, the vessel in which the consecrated wafer is placed during the benediction; it is usually made of a metal frame, to contain a glass vessel, through which the wafer is seen. Some of them are of very beautiful and rich design.

MONUMENT, (from the Latin, *monumentum*, a memorial) a structure raised to preserve the memory of some eminent person, or to perpetuate some remarkable event.

Monuments at first consisted of stones erected over the tombs of the deceased, on which were engraved the name, and frequently the actions, of the person to whose memory they were reared.

Monuments received different names among the ancients, according to their figure. When the base was square, and the solid erected thereon a prism, the monument was called *steles*; whence square pilasters, or attic columns, are supposed to be derived. When the base was circular, and the solid erected thereon a cone, the monument was called *stylos*. Those monuments that were square at the foot, and tapering therefrom in planes to a point in which the planes ended, were called *pyramids*. Others, which had triangular bases, and their sides ending in a point, were called *obelisks*; being constructed in imitation of the instruments or spits used in roasting the sacrifices.

MONUMENT OF LYSICRATES. The choragic monument of Lysicrates, commonly called the *Lantern of Demosthenes*, is the most beautiful edifice of antiquity of its size.

This monument, which is exquisitely wrought, stands near the eastern end of the Acropolis. It is composed of three distinct parts. First, a quadrangular basement; secondly, a circular colonnade, the intercolumniations of which are entirely closed up; and, thirdly, a *tholus*, or cupola, with a beautiful ornament upon it.

The quadrangular basement is entirely closed on every side, so as to exclude entrance. On breaking through one of the sides, it was found not to be quite solid; but the void is so small, and irregular, that a man can hardly stand upright in it.

This basement supports the circular colonnade, which was constructed in the following manner: six equal panels of white marble, placed contiguous to each other, on a circular plan, formed a continued cylindrical wall; which of course was divided, from top to bottom, into six equal parts, by the junctures of the panels. On the whole length of each juncture was cut a semicircular groove, in which a Corinthian

column was fitted with great exactness, and effectually concealed the junctures of the panels. These columns projected somewhat more than half their diameters from the surface of the cylindrical wall, and the wall entirely closed up the intercolumniation. Over this was placed the entablature, and the cupola, in neither of which any aperture was made, so that there was no admission to the inside of this monument, and it was quite dark. It is, besides, only 5 feet 11½ inches in the clear, and, therefore, was never intended for a habitation, or even a repository of any kind.

An entrance, however, has been since forced into it, by breaking through one of the panels; probably in expectation of finding treasures here. For in these countries such barbarism reigns at present, every ancient building which is beautiful, or great, beyond the conception of the present inhabitants, is always supposed by them to be the work of magic, and the repository of hidden treasures. At present three of the marble panels are destroyed; their places are supplied by a door, and two brick walls, and it is converted into a closet.

It should be observed, that two tripods with handles to them, are wrought in basso-relievo on each of the three panels which still remain. They are perhaps of the species which Homer and Hesiod describe by the name of τρίποδες ὠτώεντες, or *eared tripods*.

The architrave and frieze of this circular colonnade are both formed of only one block of marble. On the architrave is cut the following inscription:

ΛΥΣΙΚΡΑΤΗΣ ΛΥΣΙΘΕΙΔΟΥ ΚΙΚΥΝΕΥΣ ΕΧΟΡΗΓΗΣΕ
ΑΚΑΜΑΝΤΙΣ ΠΑΙΔΩΝ ΕΝΙΚΑ ΘΕΩΝ ΗΥΛΕΙ
ΛΥΣΙΑΔΗΣ ΑΘΗΝΑΙΟΣ ΕΔΙΔΑΣΚΕ ΕΥΑΙΝΕΤΟΣΗΡΧΕ

From this we may conclude, that on some solemn festival which was celebrated with games and plays, Lysicrates of Kikyna, a demos or borough-town of the tribe of Akamantis, did on behalf of his tribe, but at his own expense, exhibit a musical or theatrical entertainment; in which the boys of the tribe of Akamantis obtained the victory; that in memory of their victory, this monument was erected; and the name of the person at whose expense the entertainment was exhibited, of the tribe that gained the prize, of the musician who accompanied the performers, and of the composer of the piece, are all recorded on it; to these the name of the annual archon is likewise added, in whose year of magistracy all this was transacted. From which last circumstance it appears, that this building was erected above 330 years before the Christian æra; in the time of Demosthenes, Apelles, Lysippus, and Alexander the Great.

Round the frieze is represented the story of Bacchus and the Tyrrhenian pirates. The figure of Bacchus himself, the fauns and satyrs who attend him on the manifestation of his divinity, the chastisement of the pirates, their terror, and their transformation into dolphins, are expressed in this basso-relievo with the greatest spirit and elegance. The cornice, which is otherwise very simple, is crowned with a sort of Vitruvian scroll, instead of a cymatium. It is remarkable, that no cornice of an ancient building, actually existing, and decorated in this manner, has hitherto been published; yet temples, crowned with this ornament, are frequently represented on medals; and there is an example much resembling it, among those ancient paintings which adorn a celebrated manuscript of Virgil, preserved in the Vatican library. This cornice is composed of several pieces of marble, bound together by the cupola, which is of one entire piece.

The outside of the cupola is wrought with much delicacy; it imitates a thatch, or covering, of laurel leaves; edged with a Vitruvian scroll, and enriched with other ornaments. In certain cavities on its upper surface, some ornament, now lost, probably a tripod, was originally placed.

It was the form of the upper surface of the flower, and principally, indeed, the disposition of four remarkable cavities in it, which first led to this discovery. Three of them are cut on the three principal projections of the upper surface; their disposition is that of the angles of an equilateral triangle; in these the feet of the tripod were probably fixed. In the fourth cavity, which is much the largest, and is in the centre of this upper surface, a baluster was in all likelihood inserted; its use was to support the tripod.

It is well known that the games and plays which the ancient Grecians exhibited at the celebration of their greater festivals, were chiefly athletic exercises, and theatric or musical performances; and that these made a very considerable, essential, and splendid part of the solemnity. In order, therefore, to engage a greater number of competitors, and to excite their emulation more effectually, prizes were allotted to the victors; and these prizes were generally exhibited to public view during the time in which these games were celebrated.

Monument, *The*, absolutely so called among us, denotes a magnificent pillar, designed by Sir C. Wren, and erected by order of parliament, in memory of the burning of the city of London, anno 1666, near the place where the fire began. This pillar, begun in 1671 and finished in 1677, is of the Doric order, fluted, 202 feet high from the ground, and 15 feet in diameter, of solid Portland stone, with a staircase in the middle, of black marble, containing 365 steps. The lowest part of the pedestal is 28 feet square, and its altitude 40 feet; the front being enriched with curious basso-relievos. It has a balcony within 32 feet of the top, and the whole is surmounted with a curious and spacious blazing urn of gilt brass.

MOORISH, Moresque, Arabian, or Saracenic Architecture.—The style of building indifferently designated by any one of the above titles, is that which was practised by the Arabs, or Moors, and which, owing to the migratory condition of that race, and to their widely-spread influence, prevailed in many parts of the eastern continent. It is sometimes styled Mohammedan, for under the auspices of that faith it chiefly flourished; and amongst the edifices which Islamism gave rise to, are to be found some of the most magnificent and characteristic examples of the style. Previous to the time of Mohammed the Arabs seem to have possessed but little knowledge of the arts, and to have made little progress in the art of building until the commencement of the Ommiad dynasty. They would appear to have acquired a great portion of their knowledge of the arts from the various nations they subdued, during the reign of Omar, who died A. D. 644. It was this prince who founded a mosque, still called after his name, on the site of the ancient temple at Jerusalem, and which, by the additions and embellishments of succeeding kaliphs, has been reared into a large and magnificent pile. With the commencement of the Ommiad dynasty, was introduced a taste for the cultivation of the fine arts, and after the first kaliph of that house had removed the seat of empire from Medina to Damascus, the Moors began to assume the refined manners and the magnificence of the more polished Asiatic empires. During this and the following reigns, Damascus was adorned with numerous and splendid public buildings, amongst which the great mosque, founded by Alwalid I. is particularly celebrated. This prince was the first to introduce the minaret, an appendage which, although an innovation at the time, has now become a marked characteristic of Mohammedan buildings. He like-

wise made considerable additions to the mosque of Medina, and enlarged and adorned that built by Omar at Jerusalem to which we have referred above; in short, he expended a great portion of his revenues in the promotion of architecture, an example which was followed by his subjects generally.

The zeal of this race, however, in the promotion of the fine arts was surpassed by the house of El Abbas. The second kaliph of the Abassides removed the seat of empire from Damascus to Bagdad, which was founded by Almansur, A. D. 762, and continued in affluence and splendour for the space of five hundred years. "In the structure and decoration of this city, neither labour nor expense were spared, and the details of the gorgeous magnificence of the kaliph's palace would almost exceed the ordinary limits of belief, were they not authenticated by contemporary and ocular testimony."

Egypt and Africa were at an early period in possession of the Arabs, and the seat of empire was placed at Cairo, which was founded by the victorious general, Akbah, and flourished chiefly under the Fatimite line of kaliphs, who in the tenth century founded the new city of Cairo, and affected to rival the kaliphs of Asia in the splendour and magnificence of their buildings. Numerous vestiges of their edifices still remain, and amongst the most stately must be enumerated the great mosque, which is accounted the most magnificent in Barbary, and is said to be supported by five hundred columns of granite, porphyry, and Numidian marble.

But of all the Moors, those of Spain were surpassed by none in the magnificence and grandeur of their buildings, which rivalled, if they did not excel, those of Damascus, Bagdad, and Cairo, even in their most palmy days. The exceeding splendour of the mosque at Cordova, and of the palaces of the Alhamra and El Genaraliffe, places those buildings on an equal footing with the most celebrated cities of antiquity; and as the remains here are more numerous, and withal better known and more readily accessible, than those of Asia or Africa, they are usually made to form the groundwork of an examination of the general style, and to afford examples of its application;—a practice which we shall adopt in the present article.

It is remarkable that while the Arabs were diffused so widely over the earth's surface, the style of architecture adopted by them retained in every place a striking identity. It is true that differences of detail may be found in different places, as well as variety of application, yet in every country their buildings retain a very close general resemblance. This similarity is to be accounted for probably by the peculiarity of their religious creed, which, wherever it is professed, diffuses a close uniformity of habits, manners, and opinions. Notwithstanding, however, this general resemblance, which is amply sufficient to identify all buildings of this race as belonging to the same style, it must not be understood that, as a style, the Moorish was at any given period exactly the same in different countries under their dominion, or in one country at different periods, or even at the same period, for such was not the case. Indeed, if we may judge from the remains of some edifices in Asia and Egypt, of apparently the same date, we shall perceive many distinctions not only in the minutiæ of the ornamental and apparently characteristic ornaments, but also in their distribution. It is to be regretted that we have but little knowledge of the Asiatic and African remains of this style, for we are thereby prevented instituting a satisfactory comparison between the example of different localities and dates. The edifices of Spain, of which we have no inconsiderable information, must suffice as a type of the style, for which purpose they will probably serve better than those of any other country.

Various opinions as to the merits of this style have been entertained by various writers, some speaking of it in a very disparaging manner, as fanciful and capricious, whilst others extol it as elegant and poetical. It is in truth eminently fanciful, but this we judge to be rather to its praise than otherwise, as evidencing a lively and fertile imagination on the part of their architects: their buildings are indeed the embodiment of a luxuriant fancy, tempered, however, in most cases with taste and judgment. It is true that this style may not rank amongst the higher examples of the art, for it is notably deficient in constructive science; and in this feature it falls immeasurably below its rival in variety and luxuriance—the Gothic or Pointed style. In the latter the construction is paramount; in the former it is made entirely subservient to ornamentation.

Nevertheless, although Arabian architecture does not present that appearance of strength and security which is to be looked for in the perfection of the art, it never fails to gratify the eye as well as the imagination, by the richness of its picturesque and fantastic decoration; for all its parts are perfectly symmetrical, and never degenerate into heaviness or incoherence. Neither do we mean to assert that the Arabians erected their buildings without any reference to the principles of construction, for we know that they had attained great proficiency in the mathematics, and we can scarcely suppose that they neglected to apply them to such a purpose; indeed, we have very satisfactory proof to the contrary in the durability of their buildings. We are equally unacquainted with the rules by which they were guided, or the proportions which they observed in the art, and yet we know that they worked by well-defined rules, and that numerous treatises were written upon the subject, as we learn from the Arabian MSS. in the Escurial. Their ideas of design in this art must have been borrowed from a great variety of sources, amongst which may be enumerated the edifices of Egypt, Syria, India, Greece, Rome, and Byzantium, and out of all these they eliminated a style which is perfectly distinct from every one of them. All these styles, diverse as they are, were blended together with such taste and skill, and the borrowed forms so moulded and adapted, as to form one harmonious and perfect whole. The style, which is eminently peculiar, would seem to have been a development of their religious creed; it breathes the very spirit of Islamism; it is sensual and voluptuous, and appeals to the gratification of the senses rather than to the higher and nobler faculties of the mind: the Egyptian awes by its grandeur; the Grecian elevates by its purity; the Gothic humbles by its solemnity; but the Moorish gratifies only by its luxury. Of all the Mohammedans, the Turks seem to have deviated most widely from the general character of this style, by giving a preponderance to the Byzantine peculiarities by which they were surrounded in their chief city, Constantinople.

Amongst the characteristics of Moorish architecture the *horse-shoe* arch stands conspicuous. This is sometimes called the *crescent* arch, a name which may probably give us some clue to the reasons for the adoption of this form, which is indeed that of a crescent, the peculiar symbol of the Mohammedan faith; in imitation of which, it is reasonable to suppose it was introduced in a prominent position in their buildings. We shall the more readily concur in this suggestion, when we consider that such a form could not have been dictated by any principles of construction; against which it offends not a little. We must therefore look for some other reason, and that not a weak one, which could induce the Arabians to disregard the ordinary and simple axioms of construction; and we think we find a sufficient one in the idea just broached, that it was to symbolize their religious faith. The fact that

it was named by the Mohammedans, the sacred arch, will tend to corroborate this statement. The shape was first introduced into architecture by Muavia, the first of the Ommiad dynasty, who adopted it in all the buildings he erected, and it afterwards became common in all countries into which the Moors had penetrated. The same outline is found in the bulbous dome, which is so peculiar a feature of the Mohammedan mosque; and there can be no doubt but that this dome was suggested by the crescent arch, no more indeed than that the semicircular or segmental domes were derived from the corresponding arches. We might say that the probability in the former case is the stronger, inasmuch as that form of dome is scarcely natural, and not to be accounted for by requirements of construction. The profile of the bulbous dome is precisely that of the horse-shoe arch. Another instance in which the crescent-shape appears, is the cusping or scalloping of the soffit, or sometimes of both outlines of the arch, which is a common practice, and may have given rise to the use of cusps in Gothic architecture.

The profile of the horse-shoe arch is that of a segment of a circle greater than a semicircle, or, in other words, it is a circular segmental arch, which is struck from a centre above the springing line. A modification of the same form is used, which may be termed the *pointed-crescent* or *horse-shoe* arch. This form consists of two segments meeting in a point at the apex, and is struck from two centres, both, as before, above the springing line.

The *semicircular* arch was borrowed by them, and used occasionally in conjunction with the others. The *pointed* arch is by some supposed to be invented by the Arabians, and to have been copied from them by the Gothic architects; be this, however, as it may, it is certain that it was extensively in use amongst them, and is found in Persia, Egypt, and Arabia, but was most prevalent at Bagdad and in the East. It is said to have been introduced by the house of El Abbas, who adopted it in opposition to the crescent form which had been employed by the rival house of the Ommiades; but even by them the old form was not entirely discarded, being retained in the principal entrances, and also in the form of the domes.

Another variety of arch is the *stilted*, which is of semicircular form, the centre from which it is struck being taken, as in the case of the horse-shoe arch, somewhat above the springing line; but instead of the circle being continued downwards, and contracted in width towards the impost line, the ends of the semicircle are carried down straight or perpendicularly, so as to give an appearance of elevation and lightness to the arch, which it would not otherwise possess.

The last form which we shall notice is the *cusped* or *scalloped* arch, the outline of which is similar to the polyfoil-headed compartments in Gothic apertures, being produced by three or more intersecting semicircles. There is this difference, however, that whereas the Gothic examples are merely ornamental accessories, the Moorish form main parts of the construction; the scallops are large and form the outline of their main arches, the extrados as well as the intrados following the same profile.

All the above forms of arches are treated in various ways, both as to their impost and decoration. Sometimes the arch springs directly from the solid wall, at other times it is made to rest upon columns. In the case of the horse-shoe arch, when the former arrangement takes place, the whole of the arch rests upon the wall, or, in other words, the wall projects as far as the most prominent part of the arch, so that the arch does not overhang the impost; but in the other arrangement, the columns are recessed back so as to range with the extremity of the diameter with which the arch is struck, thus leaving a space between the columns as wide as the diameter or extreme width of the arch; the capital of the column, or an impost moulding above it, projects forward so as to sustain the extremities of the arch. Sometimes, but more especially when *stilted*, the arch is supported by corbels projecting from the walls, and serving as imposts. This practice of corbelling is very prevalent. In some cases the face of the arch, that is, the width between the intrados and extrados, is continued down the impost-jambs, but in others it stops at the springing. This face again varies considerably in breadth, and sometimes is not shown at all on the face of the wall; it is generally, however, a wide band or archivolt following the outline of the arch, sometimes plain, showing only the joints, sometimes plain with the addition of a moulding round the extrados, and at others both moulded and otherwise decorated. The decoration is usually in compartments formed by the joints, and frequently the alternate voussoirs are contrasted by a difference of ornamentation. The depth of the archivolt was sometimes so great as to equal the radius. Cusping in the direction of the outline of the arch is a common mode of decoration, being sometimes applied in the shape of a moulding round the extrados, and sometimes the intrados or soffit only being so cut or serrated. Occasionally the arches of apertures are left blank, being filled up with walling, and having a square-headed aperture underneath: this is especially the case with the crescent arch. Arches of whatever kind are generally placed within a square-headed panel or compartment, which is frequently surrounded by a border or plat-band, somewhat similar to the square hood-mould of the perpendicular period of Gothic architecture. This band, as well as the spandrels intercepted between it and the arch, are usually covered with ornamentation of various descriptions. Sometimes two plat-bands are introduced, with a space between them, which is commonly filled up with inscriptions or other decoration. This last method, however, is not common except in large apertures, or in principal entrances.

The columns are of slender proportions, and remarkable for extraordinary lightness and variety of form. Their shafts are sometimes plain, but often ornamented with carving, being sometimes surrounded with a spiral groove twisting round the shaft, at others grooved perpendicularly. The capitals are of various forms, usually carved into clustered foliage, being sometimes imitations of the classic orders, and sometimes designs of their own; the cap is covered with a plain abacus. Columns were very frequent in Arabian edifices, disposed in clusters or rows, and supporting low arcades; they add considerably to the light appearance of their buildings.

Corbelling, which consists in the projection of stones or bricks at regular distances from the main wall, is of extensive use in Arabian architecture, and was probably introduced into Europe by them. The practice seems to have originated in the East, for it is seen in Eastern edifices of very early date, and prevails to a great extent in the architecture both of India and China. The Arabians employed corbels in all their structures, but more especially in their fortresses, to throw out the parapets for machicolations.

Amongst the many peculiarities of Arabian art, perhaps none is more worthy of mention than that method of ornamentation which has been designated under the title of *arabesques*, although the term, as applied by the moderns, does not exactly describe the peculiar ornament alluded to; with us, the term includes a wider range of decoration. The law of the Mohammedan faith prohibited all representations of human or animal figures, as bordering too closely on the practices of Christianity and paganism, and this precept was

at first very strictly adhered to. Their arabesques therefore, excluding all forms of animal life, consisted entirely of representations of fanciful plants, stalks, and foliage, treated in an artistic manner, and gracefully entwined in an endless variety of form; these were introduced on the walls, sometimes in colour only, but very often in stucco, the pattern standing out from the wall in high relief.

Another style of decoration, very similar to the last, consists of panels or compartments filled with lines or bands, disposed in an infinite diversity of geometrical figures, and interlacing one with another in such a manner as to form a sort of labyrinth, whose arrangement and combination was unintelligible, except by close observation. Of this method of decoration, a writer on the subject very justly observes—"Their geometrical patterns exhibit singular beauty and complexity, inexhaustible variety of combinations, and a wonderful degree of harmonious intricacy, arising out of very simple elements; to which must be added the variety produced by colour also, whereby the same arrangements of lines and figures could be greatly diversified. Hence, though apparently quite unmeaning, and intended only to gratify the eye, such embellishment must have powerfully recommended itself to a people both imaginative and contemplative, and whose fancy would find occupation in patiently tracing and unravelling the manifold intricacies and involvements, the mazes of what at first sight looks like a mere labyrinth, until its scheme unfolds itself; but merely momentarily, as it were, being again lost when attention is diverted from it to particular parts.

Another method of decoration, which was very prevalent, and is to some extent a characteristic, consists in the application of inscriptions as a means of enrichment. This custom was in all probability borrowed from the Egyptian practice of inscribing hieroglyphics on their walls; although the idea is somewhat differently applied. A nearer approach to the Arabian system, is seen in that adopted by the Gothic architects, the application in both instances being almost identical. The most usual position for such inscriptions was round their doors and windows, or on the surface of bands, architraves, and friezes; they were usually raised in relief from the surface of the wall, and oftentimes inlaid similarly to mosaic work, and richly illuminated with precious stones; in almost all cases, they were enriched with gilding and colour, and the characters rendered as calligraphic as possible. The inscriptions which mostly prevailed, were sentences from the Koran, sometimes other moral and religious precepts, and occasionally passages of Oriental poetry, the nature of the inscription varying in accordance with the requirements of the place or building they enriched.

Another addition to the decorative character of the style, is seen in the open trellis-work employed to close apertures—a happy contrivance for excluding the rays of the sun at the same time that it admitted freely both light and air; a matter of great importance in a warm climate. The idea is supposed to have been derived from network, suspended before apertures for the same purposes, as well as for the exclusion of insects; it is decidedly of Oriental origin. This fret-work is composed of bands interlaced, and forming an infinite variety of figures, and is very similar to the geometrical patterns we alluded to above.

The designs are often very elegant; and although they appear somewhat intricate at first, upon closer examination it will be found that they are composed of simple parts as simply put together, and yet they produce a great variety of tasteful patterns, in which the star is not unfrequently a prominent figure. The same eulogy will apply to this lattice-work, as to the geometrical arabesques. A similar method of interlaced work, is not unfrequently to be seen in their pierced parapets, which were common in the edifices of the East.

The floors, and sometimes a portion of their walls, were inlaid with mosaic work, disposed in various patterns, in which the interlacing band again makes its appearance, and with like success. The roofs are often coffered or recessed in panels in a very peculiar manner, which gives to them very much the appearance of a honeycomb; sometimes also they are covered with pendants, in such a way as to realize the idea of stalactite caverns. A very beautiful method of lighting their baths from the roof, has been noticed and extolled by almost every traveller; small star-shaped apertures are cut in a sloping direction through the roof, and while their form delights by its beauty and propriety, they admit only a subdued degree of light.

On the whole, when we consider the fantastic form of the arches, the slender proportions of their columns, the infinite variety and profuseness of their decorations, and remember that the entire edifice was enriched with the most brilliant colouring, it must be confessed that it would be difficult to picture a more vivid realization of our notions of fairy-land, than is presented to us by such a description.

Notwithstanding, however, the gorgeousness of their interiors, the Arabs, of Spain especially, paid little attention to external decoration. The exterior of their edifices is decidedly plain, sometimes approaching to rudeness, frequently composed of irregular masses of scattered buildings, without symmetry, or any attempt at ornament, and to be admired only for their bold outline and picturesque effect. One circumstance which adds to their heavy, massive appearance, arises from their custom of lighting their halls from the interior courts, so as to escape as much as possible the heat of the sun.

Their mosques and other buildings in the East presented a less rude exterior, the outline being broken up and varied by the numerous domes and minarets, the lofty and slender forms of the latter forming a picturesque contrast with the swelling curves of the former. These minarets are light circular towers, elevated above the rest of the building, with projecting galleries round the upper part, whence the imaum called to prayer; they are usually enriched with a profusion of delicate fret-work. Many mosques were covered with a multitude of domes, one principal one being larger than the others which surrounded it. The walls too are more enriched than those of the buildings in the West, and altogether the exteriors were of a much lighter and elegant description. *See* MOSQUE.

M. Laborde, in his voyage "Pittoresque de l'Espagne," divides Arabian architecture of Spain into three distinct chronological periods: the first of which dates from the establishment of Islamism to the ninth century; the second from the ninth to the thirteenth century; and the last, from that period to the decline of Mohammedan influence in Spain. The mosque of Cordova has been selected as the most apt type of the first period: a building which bears a close resemblance to the later works of the Romans, the plan corresponding in many respects with the oldest churches in Rome, and the materials being either procured or coarsely imitated from the Basclaine, which had been previously erected in Spain by the Romans.

In the second period, we see a considerable advance in elegance, of which the palace of the Alhambra presents a favourable example. In this period, most of the traces of the Byzantine style disappear, and the new style is seen in a state of perfect development; indeed, the examples of this date are of greater beauty, and more correct taste, than those either preceding or following it.

The third period shows a decline in art, and its examples exhibit a mixture with the style then prevalent in Italy, and which was spreading itself throughout Europe. M. Laborde found specimens of this style in the fortresses of Benevente, Pennafiel, Cordesillas, Segovia, and Seville. At this date the plans continued much the same as before, but Greek ornaments began to be employed, and Corinthian columns are frequently seen supporting Moorish arches. The restrictions also respecting the representation of living figures began to be less strictly adhered to.

We forthwith proceed to give a description of some of the more noted Spanish structures of this style, at the head of which in point of date, if not of importance, stands the mosque of Cordova.

This place is stated to have contained no less than 600 mosques, 900 baths, and 2,000 houses. Of these buildings the mosque to which we allude was one of the most important; it was commenced by Abdurrahman in the eighth century, and completed by his son and successor, Hisham, in the same century, since which period it has been frequently enlarged and enriched by subsequent kaliphs. The plan of the building is a rectangle or oblong, whose longest side from north to south is 620 feet, and that from east to west 440 feet; the whole space being enclosed by a wall with counterforts, both of which are embattled, and surrounded by four streets, which renders it isolated from all other buildings. The wall is 8 feet thick, and varies in height from 35 to 60 feet. The entire space enclosed by it, is divided into two parts, the first of which, at the northern extremity, was the court in which the Moslems performed the requisite ablutions ere entering the mosque. This quadrangle measured 210 feet in depth, and was surrounded by a colonnade of 72 columns enclosing three fountains. The remaining space is occupied by the mosque, which is divided internally into 19 naves, running from north to south, and extending in length about 400 feet, and into 32 from east to west. Each of the naves from south to north is about 16 feet wide, and those in the cross direction somewhat less, and are separated from each other in both directions by rows of columns, whose number amounted in all to 850, to which, if we add the 72 in the external colonnade, we shall have a total of 922 columns. They were composed of jasper and the richest marbles, measuring 18 inches in diameter, and on an average 15 feet in height: their capitals are of various designs, but all approaching the Corinthian or Composite in form, and upon these spring the arches. There were no less than 21 entrances, the doors of which were all covered with the best Andalusian brass. The cupola was 72 cubits, or 108 feet in height, and was surmounted by three apples, two of which were of pure gold, and the central one of silver, each measuring three spans and a half in circumference. The ceilings were of wood painted, each range forming on the exterior a small-roof, separated from the adjoining one by a gutter. The chief entrance that led into the Maksura or sanctuary, is said to have been formed of gold, as were also the walls of the Mibhra or chancel: the floor of the Maksura was of pure silver, and in it, on a throne of wood of aloes, with nails of pure gold, was preserved, in a case of the same metal set with pearls and rubies, the principal copy of the koran. The pulpit was formed of the most precious woods, such as ebony, sandal, brazil, citron, and wood of aloes, and occupied a period of seven years in its manufacture. The interior of the edifice was lighted by 280 chandeliers of brass and silver, containing 11,000 lamps.

Cordova once possessed a palace, which, according to the accounts of Mohammedan writers, was of the greatest magnificence; of this, however, although of more recent erection than the mosque by two centuries, we have no remains: it is said to have been adorned with 4,000 pillars of marble, and to have had floors of the same material.

The Alhambra is the most perfect and beautiful building of this style with which we are acquainted, and one of which we have more detailed information than of any other. It is situated on the northern brow of one of the steep hills of Granada, and is approached from the city through a narrow street, which leads to the entrance, called the Gate of Judgment, so named from the ancient practice of holding the courts of justice at the entrance of cities. This gate is a square tower, with an entrance under a large horse-shoe arch, which reaches half-way up the tower, and has an open hand sculptured on the key-stone, emblematical of the omnipotence of the Deity. The gate is of white marble, which, however, has become much discoloured through age and exposure; it is decorated above with mosaic tiling, about 3 feet 4 inches in height, beneath which is an inscription in Cufic characters, of the motto "There is no conqueror but God," and beneath this again on the keystone of the arch is sculptured a key, one of the principal symbols of the followers of Mohammed.

The entire plan of the building measures 2,300 feet, by 600 feet, and is divided into several courts, all upon the same plane. The first of these is the court of cisterns, so named from the cisterns which it contains, and which supplied the palace with water. The largest cistern is 102 feet long, and 56 feet wide, the whole being enclosed by a wall 6 feet thick, and covered over with an arch 47 feet 6 inches in the centre, and 17 feet 6 inches below the surface of the ground. There are two circular apertures 25 feet 6 inches apart, and 3 feet 6 inches in diameter, strongly built, and carried up 3 feet 6 inches above the level of the ground. The water is by this means kept in a constant state of coolness; in warm climates, a matter of some importance.

On the north side of the Court of Cisterns, is the Mesuar, or common bathing-court, which is an oblong of 150 feet by 56 feet. This hall is more enriched than the last, which leads us to notice a common practice of the Moors, that of increasing the luxury and magnificence of their decorations towards the interior of their buildings. In this hall there is an arcade springing from very light marble columns, of which material the floor also is composed; the walls are covered with mosaic tiling up to the ceiling, in which are small apertures in the shape of stars, lined with green-glazed tiles, to assist ventilation, and diffuse a refreshing coolness throughout the building. The bath-rooms of the kaliph and sultana are very richly finished, ornamented with gilding and porcelain: the basins are of white marble, and the walls are covered to the height of the cornices with black and white mosaics. The roof is of stone, vaulted, and is perforated for ventilation, as above.

At the lower end of the Mesuar is the Court of Lions, which is considered one of the most splendid examples of Moorish architecture still existing. It is, like the others, an oblong court, measuring 100 feet in length by 50 in breadth, and is surrounded with a corridor or arcade, supported by 128 columns of white marble, 9 feet high, and 8½ inches in circumference. The capitals vary in design; each design being frequently repeated, but similar designs being placed without any regard to regularity. The columns also are disposed irregularly, sometimes singly, at others coupled, and occasionally in groups of three.

The arches are of different sizes, the larger being 4 feet 2 inches wide, the smaller about 3 feet. They are enriched with a profusion of highly finished arabesques, and surmounted with an inscription; a rich cornice runs round the

entire court. The floor of the colonnade is laid with white marble, and the dado of the walls is formed of a lining 5 feet high, of brilliant yellow and blue mosaic tiling, with a border containing the inscription, "There is no conqueror but God," in blue and gold. At each end of this court projects a kind of portico, supported, like the colonnade, with light marble columns and arches, and having a fine stuccoed ceiling. In the centre of the court stands the celebrated Fountain of Lions, which consists of an alabaster basin, richly decorated, supported on the backs of twelve lions, and carrying another smaller basin above, from which the water fell into the larger one, and thence through the lions' mouths into a large reservoir of black marble.

From the right-hand side of the Court of Lions, is a passage to the Hall of the Two Sisters, so named, from the two beautiful slabs of white marble forming part of the pavement on each side of the fountain, and which measure 15 feet by 7½ feet, the entire surface being perfectly free from crack or stain. "The walls are decorated from the pavement to the rise of the arches, with the usual elegant mosaics; the panels between them are filled with a delicate ornament, which, at a little distance, has the appearance of a plain face; the ceiling is composed of stalactites, in stucco, and finished in a style of great elegance. The four balconies of this sumptuous apartment were appropriated to musicians; the women of the harem sat below, and a jet d'eau in the middle diffused a refreshing coolness through the hall. The windows look into a little myrtle garden."

On the other side of the Court of Lions, and opposite that of the Two Sisters, is the Hall of the Abencerrages, said to be so called, from the circumstance of some noble Arabs having been put to death there by one of the kings of Granada. "It appears to have been a central saloon, opening a communication to the other parts of the palace. Every possible variety of combination which can be devised by ingenuity and patience, are formed on the walls and ceiling; the lines regularly cross each other in a variety of directions, and return again to the point from which they were first projected. The extraordinary designs are thought to have been produced by pouring prepared gypsum into moulds, and, after it was applied to the walls, painting them with gold, azure, and purple.

"The concert-room of the baths is a lofty saloon, in which the royal family listened to the concerts of musicians, stationed in an elevated tribune, while the audience sat below on rich carpets. The columns are of white marble, and the mosaics between the columns are black, green, yellow, and white, set in a green border; the roof is covered with tiles, and the woodwork richly ornamented, especially the three lattices or windows."

The Hall of the Ambassadors is a square court, the sides of which measure 36 feet, and the height 64 feet. It is entered through an arched door, decorated profusely with arabesques in stucco, coloured in blue and gold. The walls are covered with mosaics of various patterns, interspersed with inscriptions formed in porcelain, and made to form a most harmonious combination with the stucco arabesques; the cornices are enriched with the same inscription as in the other halls. The ceiling is arched and decorated with great variety of chiligon mosaics, knots, and other ornaments; and gold, silver, and azure purple, are the colours covering the coloured facets; the floor is inlaid with mosaics. The walls of this hall are of an immense thickness, no less than 15 feet on three sides, and 9 feet thick on the fourth; they are composed of a mixture of pebbles and red clay. "The ceiling is composed of strong pieces of larch, in admirable preservation, which are keyed and fastened together in such a manner, that, on pressing the feet on the centre of the ceiling, the whole vibrates like a tight rope. The roof is formed of a scantling of 10 inches square deal, and laid close together, with cross-braces at the angles. Bricks are laid on these rafters, and upon them is a coating of lime; on these are placed the bricks and tiles forming the exterior covering of the roof.

"The walls of this splendid building are formed throughout of a sort of rubble-work mixed with clay, and were, on an average, 7 feet in thickness, flanked with solid towers 18 feet thick; bond-timbers of pine were inserted in the walls, and at other times, strands or twists made of rush were inserted for the same purpose; nails were driven into the walls to receive the plaster, being first coated with gypsum to prevent corrosion, but when timbers were to be plastered, they twisted Esparta cords round them to bind the plaster. The bricks with which the open courts are paved, are 14 inches long by 7½ wide, and 3 inches deep; the underside had a groove sunk in it about 2½ inches wide and 1 inch deep, and extending the length of the brick, for the purpose of forming a good bond with the cement. When these bricks were laid over boarding, a layer of potters' clay, or of bricks laid dry, was placed between the timber and the paving.

"The durability of the woodwork throughout this building is surprising, it is mostly of pine, and has withstood the attacks of dry-rot, worm, and every other insect, without injury; it seems now perfectly sound, and free from every sign of decay, and it is even stated, that, in the Court of Lions, the ancient woodwork is perfect, whilst that of later date is rapidly decaying." The Spaniards attribute this durability to the timber being coated with a composition consisting of Safne glue and garlic well pounded in a mortar; these being mixed together, with the addition of vermilion, are boiled over a gentle fire, until the glue becomes as thin as water; too much or too little boiling deprives it of its viscous property. Planks cemented with this composition are said to adhere so firmly, as to break at any other part except at the joint. Garlic being noxious to worms, the Moors evidently mixed it with their cement, in order to prevent their depredations; it is not improbable that it was mixed with the gypsum used in the Alhambra, which may account for the stucco work remaining uninjured either by spiders or insects. Some suppose that this durability arises from the trees having been lanced or deprived of their sap when felled.

The durability of the Arabian buildings of Spain will appear more marvellous when contrasted with other buildings. The wooden gate of Cyprus, belonging to the celebrated temple of Diana, is said to have existed for four centuries, and that of the old church of S. Peter at Rome, which was composed of the same material lined with sheets of silver, continued undecayed for 550 years, but the beams employed in the construction of the roof of the mosque of Cordova manifest no symptoms of decay after a lapse of 1,000 years.

The arabesques, paintings, and mosaics, which give so great a charm to this building, are very highly and carefully preserved. The former appear to have been cast in moulds, and fixed to the walls in pieces so accurately connected, that no sign of juncture is visible. The ornaments which recede from the eye are coloured in gold, pink, light blue, and dusky purple, the first colour being nearest to the eye, and the last farthest from it, the general surface being white, which is remarkably pure and splendid. All the colours are fresh and bright, and, if the dust be removed, appear in all their pristine beauty.

The domes and arcades are formed of artificial casts, which are almost as light as wood, and as hard as marble, having endured the test of ten centuries.

A house built during the third period still exists at Seville, which was the residence of a Moorish Arab chieftain; the whole is most voluptuously contrived for a warm climate, and is in the most perfect state of preservation, though upwards of 500 years old; one of the apartments is almost perfect of its kind. The form resembles a double cube, the one placed above the other, its height about 60, and its length and breadth about 30 feet. The ornaments begin at about 10 feet from the floor, and are continued to the top of the room: they consist of a kind of variegated network of stucco, designed with the most perfect regularity, and yet most admirable variety in the patterns and the interlacings of each. This edifice has often been adduced as an instance of the wonderful superiority of the Arabs over the modern Spaniards in the art of building.

There is one very ancient and remarkable building which we have not here described, but which may not be passed over without notice; we allude to the CAABA, of which a description will be found under that head.

For further and more detailed descriptions of this style of building, we refer the reader to the elaborate works of Jones and Murphy.

MOOR-STONE, a very remarkable stone, found in Cornwall, and some other parts of England, used in the coarser works of modern builders. It is, in fact, a white granite, and is a very valuable stone. It is very coarse and rude, but has beautiful congeries of variously constructed and differently figured particles, not diffused among, or running into one another, but each pure and distinct, though firmly cohering with whatever it comes in contact. Its colours are principally black and white: the white are of a soft marble texture, and opaque, formed into larger congeries, and emulating a sort of tabulated structure; among these are many of a pure crystalline splendour and transparence; and in some are lodged, in different directions, many small flaky masses of pure talcs, of several colours; some are wholly pellucid, others of an opaque white, others of the colour of brown crystal, and a vast number perfectly black. It is found in immense strata in some parts of Ireland, but is disregarded there.

It is found with us in Devonshire, Cornwall and some other counties; and brought thence in vast quantities to London. It never forms any whole strata there, but is found on the surface of the earth, in immense and unmanageable masses; to separate these, and render them portable, a hole is dug in some part of the mass, which being surrounded with a ridge of clay, is filled up with water; this by degrees soaks in, and finding its way into the imperceptible cracks, so far loosens the cohesion of the particles, that the day after, on driving a large wedge into the hole, the stone breaks into two or more pieces. It is used in London for the steps of public buildings, and on other occasions, where great strength and hardness are required.

MOOT-HALL. MOOT-HOUSE, a town-hall; hall of judgment. In the *moot-halls*, formerly connected with the inns of court, imaginary or moot-cases were argued by the students at law.

MORESK, or MORESQUE, (from the Spanish *morisco*,) a kind of painting, carving, &c., done after the manner of the Moors, consisting of several grotesque pieces and compartments promiscuously intermingled, not containing any perfect figure of a man or other animal, but a wild resemblance of birds, beasts, trees, &c.

They are also called *arabesques*, and are particularly used in embroideries, damask-work, &c.

MORTAR (from the Dutch *morter*, cement) in architecture, a composition of lime, sand, &c mixed with water.

In the construction of works in masonry, some kinds of cementitious matter is generally employed for connecting the stones together, and rendering them firm and compact. When the works are to be exposed to the action of water immediately after being built, this cementitious matter must be of such a nature, that it will harden under water. Hence it is, that we have occasion for two kinds of mortar, one that will set and harden under water, called by Smeaton a *water-mortar*, or cement; and *common mortar*, for ordinary buildings. *See* MORTAR, HYDRAULIC.

Common mortar is the substance placed between the stones or bricks of a building, to cement them together, and thus cause them to retain their places, and give strength and stability to the edifice. Mortar is essentially composed of lime and silicious sand, the first being in the state of hydrate or slacked lime: the sand is used of different degrees of fineness. The hardness of mortar is owing to the gradual conversion of the hydrate of lime into carbonate of lime, which takes place very slowly by the absorption of carbonic acid gas from the atmosphere; in this state it adheres very firmly to the particles of silica diffused through it, and both are strongly united with the material employed in the building.

In order that this change may occur with advantage, certain conditions are requisite: if the mortar dries too quickly, the carbonate formed will remain much divided, and will not acquire the necessary adhesive property; if on the other hand, the mortar be placed under water, a portion of the lime will gradually dissolve, what remains will become carbonate with great difficulty, and the particles of sand will be isolated. If, on the contrary, the mortar be long kept moist and exposed to the air, the carbonic acid gas acts slowly but incessantly on the lime, the water of which becomes gradually saturated with it, and this being transferred to the lime, it is converted into almost a crystalline carbonate, in successive portions or layers, and these adhere with great force to the particles of sand. It follows, from what has been stated, that buildings erected when the weather is too hot are less stable than those which are constructed later in the year; but it is to be observed, that during frost, owing to the freezing of the water, the absorption of carbonic acid is not only stopped, but the solidity of the mortar is destroyed by the freezing or crystallization of the water.

Much has been said as to the extreme hardness of ancient mortar, and it is supposed that some secret method was adopted in its preparation; but the fact may probably be accounted for by merely referring to the circumstance, that the long exposure which it has undergone in considerable masses has given it the opportunity of slowly acquiring the carbonic acid from the air, upon which its hardness and durability depend. It is to be observed, that lime which is not sufficiently burnt, or lime which has been slacked by the moisture which it has acquired by exposure to the atmosphere, cannot form good mortar: the first has not been deprived of the carbonic acid which it is requisite to regain slowly from the air; and the latter has re-acquired it under circumstances which diminish instead of increase the solidity of the mortar.

Other materials, such as limestone, marble, chalk or shells, may be used to burn for lime or common mortar, all these substances being composed chiefly of lime and carbonic acid; and if a piece of one of them be slowly burnt or calcined, so as to expel the whole, or nearly the whole, of its carbonic acid, it loses about 44 per cent. of its weight; and when a small quantity of water is added to the calcined matter, it swells, gives out heat, and falls into a finely-divided powder called *slack lime*. The bulk of the powder is about double that

of limestone. If this powder be rapidly formed into a stiff paste with water, it sets or solidifies as a hydrate of lime, and ultimately hardens by the absorption of carbonic acid from the air. This constitutes common building-mortar. Hydrate of lime consists of 100 parts of lime, and 31 parts of water. Common limestone consists of carbonate of lime, with very little of any other substance; it produces a white lime, which slakes freely when well burnt; it dissolves in diluted muriatic acid, with only a small portion of residue, and never contains more than a trace of iron. It differs much in external characters, as chalk, marble, common compact limestone, &c.

These limestones do not form cements to set in water, without the addition of other kinds of cementing matter; hence they are usually employed only for common mortar. The hardest marble and the softest chalk make equally good lime when well burnt; but chalk-lime will slake when not perfectly burnt, and therefore seldom has a sufficient quantity of fire; whereas stone-lime does not re-absorb carbonic acid so rapidly as chalk-lime.

Lime made from common limestone, sustains very little injury from being kept after it has been formed into mortar, provided the air be effectually excluded; indeed, Alberti mentions an instance of some which had been covered up in a ditch for a very long time, and yet was found to be of an excellent quality.

To employ lime alone in the composition of mortar would render it expensive; besides, it would be of inferior quality. The material commonly used to mix with lime is sand, and this sand should be of a hard nature, not very fine, but angular; also, the more irregular it is in size, the better. It should be free from any mixture of soft or earthy matter, if it can be procured without. The reason is obvious; for mortar, composed of soft sand, cannot be harder than that sand. Sea-sand makes good mortar, particularly water-mortar. Very hard-burnt brick, or tile, reduced to a coarse powder, also makes an excellent substance to mix with lime, for many purposes. It may be observed, although generally supposed otherwise, that there is really no chemical affinity between lime and sand, it is only a mechanical mixture.

De Lorme observes, that the best mortar is made of puzzolana instead of sand; adding, that this penetrates black flints, and turns them white. Mr. Worledge observes, that fine sand makes weak mortar, and that the larger the sand the stronger the mortar. He therefore advises, that the sand be washed before it is mixed; and adds, that dirty water weakens the mortar considerably. Wolfius recommends that the sand be dry and sharp, so as to prick the hands when rubbed; yet not so earthy as to foul the water in which it is washed.

Vitruvius observes, that fossil sands dry sooner than those taken out of rivers. Whence, he adds, the latter is fitted for the insides, the former for the outsides of a building. But fossil sand lying long in the air, becomes earthy.

Palladio takes notice, that of all sands the white are the worst, from their want of asperity.

The proportion of lime and sand in our common mortar is extremely variable: Vitruvius prescribes three parts of pit-sand, and two of river-sand, to one of lime; but the quantity of sand here seems to be too great.

The best proportion of sand for common mortar, is easily ascertained by trial; enough should be added to render the mortar rather short than tough under the trowel. The proportion varies from 4 parts of sand to 1 of lime, or $1\frac{1}{4}$ parts of sand to 1 of lime, by measure, the proportion differing according to the coarseness of the sand, the nature of the limestone, and the precautions used in burning it; all set proportions being universally adhered to only by those who are utterly ignorant of the subject. In many situations, it is impossible to procure good sand, except at an enormous expense.

Mr. Dossie, in the second volume of the *Memoirs of Agriculture*, p. 20, &c., gives the following method of making mortar—impenetrable to moisture, acquiring great hardness, and exceedingly durable—discovered by a gentleman of Neufchatel: Take of unslaked lime and of fine sand, in the proportion of one part of the lime to three parts of the sand, as much as a labourer can well manage at once; and then adding water gradually, mix the whole well together with a trowel, till it is reduced to the consistence of mortar. Apply it, while hot, to the purpose, either of mortar, as a cement to brick or stone, or of plaster to the surface of any building. It will then ferment for some days in dry places, and afterwards gradually concrete or set, and become hard; but in a moist place it will continue soft for three weeks or more; though it will, at length, attain a firm consistence, even if water have such access to it as to keep the surface wet the whole time. The lime for this mortar must be made of lime-stone, shells, or marl; and the stronger it is, the better the mortar will be. It is proper also to exclude the sun and wind from the mortar, for some days after it is applied; that the drying too fast may not prevent the due continuance of the fermentation, which is necessary for the action of the lime on the sand. When a very great hardness and firmness are required in this mortar, the using of skimmed milk instead of water, either wholly or in part, will produce the desired effect, and render the mortar extremely tenacious and durable.

Dr. Higgins, who made a variety of experiments for the purpose of improving mortar, says, the perfection of lime, prepared for the purpose of making mortar, consists chiefly in its being deprived of its fixed air. On examining several specimens of the lime commonly used in building, he found that it is seldom or never sufficiently burned; for they all effervesced, and yielded more or less fixed air, on the addition of an acid, and slaked slowly, in comparison with well-burned lime. He also recommends that, as lime owes its excellence to the expulsion of fixed air from it in the burning, it should be used as soon as possible after it is made, and guarded from exposure to the air, as much as possible, before it is used.

From other experiments, made with the view of ascertaining the best relative proportions of lime, sand, and water, in the making of mortar, it appeared that those specimens were the best which contained one part of lime in seven of the sand. Also, that mortar, which is to be used where it must dry quickly, ought to be made as stiff as the purpose will admit, or, with the smallest practicable quantity of water; and that mortar will not crack, although the lime be used in excessive quantity, provided it be made stiffer, or to a thicker consistence, than mortar usually is.

In order to the greatest induration of mortar, it must be suffered to dry gently, and set; the exsiccation must be effected by temperate air, and not accelerated by the heat of the sun or fire; it must not be wetted soon after it sets; and afterwards it ought to be protected from wet as much as possible, until it is completely indurated; the entry of acidulous gas must be prevented as much as possible, until the mortar is finally placed and quiescent; and then it must be as freely exposed to the open air as the work will admit, in order to supply acidulous gas, and enable it sooner to sustain the trials to which mortar is exposed in cementitious buildings, and incrustations.

Dr. Higgins also inquired into the nature of the best sand or gravel for mortar, and into the effects produced by bone ashes, plaster-powder, charcoal, sulphur, &c., and he deduces

great advantages from the addition of bone-ashes, in various proportions, according to the nature of the work for which the composition is intended.

This author describes an invention of his own for a superior kind of mortar, or stucco, applicable to ornamental work in imitation of stone. As the same general principles ought to be followed in making even the commonest kinds of mortar, we shall insert here the instructions given by Dr. Higgins.

Of sand, the following kinds are to be preferred; first, *drift-sand*, or *pit-sand*, which consists chiefly of hard quartose flat-faced grains, with sharp angles; secondly, that which is the freest, or may be most easily freed by washing, from clay, salts, and calcareous, gypseous, or other grains less hard and durable than quartz; thirdly, that which contains the smallest quantity of pyrites, or heavy metallic matter, inseparable by washing; and fourthly, that which suffers the smallest diminution of its bulk in washing. Where a coarse and fine sand of this kind, and corresponding in the size of their grains with the coarse and fine sands hereafter described, cannot be easily procured, let such sand of the foregoing quality be chosen, as may be sorted and cleansed in the following manner:—

Let the sand be sifted in streaming, clear water, through a sieve which shall give passage to all such grains as do not exceed one-sixteenth of an inch in diameter; and let the stream of water, and the sifting, be regulated so that all the sand which is much finer than the Lynn-sand, commonly used in the London glass-houses, together with clay, and every matter specifically lighter than sand, may be washed away with the stream; whilst the purer and coarser sand, which passes through the sieve, subsides in a convenient receptacle, and the coarse rubbish and rubble remain on the sieve to be rejected.

Let the sand which thus subsides in the receptacle, be washed in clean streaming water through a fine sieve, so as to be further cleansed, and sorted into two parcels; a coarser, which will remain in the sieve which is to give passage to such grains of sand only, as are less than one-thirteenth of an inch in diameter, and which is to be saved apart under the name of *coarse sand*, and a finer, which will pass through the sieve, and subside in the water, and which is to be saved apart under the name of *fine sand*. Let the coarse and the fine sand be dried separately, either in the sun, or on a clean iron-plate, set on a convenient surface, in the manner of a sand-heat.

Let the *stone lime* be chosen, which heats the most in slaking, and slakes the quickest when duly watered; that which is the freshest made and closest kept; that which dissolves in distilled vinegar with the least effervescence, and leaves the smallest residue insoluble, and in the residue the smallest quantity of clay, gypsum, or material matter. Let the lime, chosen according to these rules, be put in a brass wired sieve, to the quantity of fourteen pounds. Let the sieve be finer than either of the foregoing; the finer the better it will be; let the lime be slaked, by plunging it into a butt filled with soft water, and raising it out quickly, and suffering it to heat and fume; and by repeating this plunging and raising alternately, and agitating the lime until it be made to pass through the sieve into the water; and let the part of the lime which does not easily pass through the sieve be rejected; and let fresh portions of the lime be thus used, until as many ounces of lime have passed through the sieve as there are quarts of water in the butt.

Let the water thus impregnated stand in the butt, closely covered, until it becomes clear; and through wooden cocks, placed at different heights in the butt, let the clear liquor be drawn off, as fast and as low as the lime subsides, for use. This clear liquor is called *lime-water*. The freer the water is from saline matter, the better will be the cementing liquor made with it.

Let fifty-six pounds of the aforesaid chosen lime be slaked, by gradually sprinkling the lime-water on it, and especially on the unslacked pieces, in a close clean place. Let the slaked part be immediately sifted through the last-mentioned fine brass-wire sieve: let the lime which passes be used instantly, or kept in air-tight vessels; and let the part of the lime which does not pass through the sieve be rejected. This finer and richer part of the lime which passes through the sieve, may be called *purified-lime*. Let bone-ash be prepared in the usual manner, by grinding the whitest burnt bones; but let it be sifted, so as to be much finer than the bone-ash commonly sold for making cupels.

The best materials for making the cement being thus prepared, take fifty-six pounds of the coarse sand, and forty-two pounds of the fine sand; mix them on a large plank of hard wood placed horizontally, then spread the sand so that it may stand to the height of six inches with a flat surface on the plank, wet it with the lime-water, and let any superfluous quantity of the liquor, which the sand in the condition described cannot retain, flow away off the plank. To the wetted sand add fourteen pounds of the purified lime, in several successive portions; mixing and beating them up together, in the mean time, with the instruments generally used in making fine mortar; then add fourteen pounds of the bone-ash, in successive portions, mixing and beating all together.

The quicker and more perfectly these materials are mixed and beaten together, and the sooner the cement thus formed is used, the better it will be. This may be called *cross-grained cement*, which is to be applied in building, pointing, plastering, stuccoing, or other work, as mortar and stucco generally are; with this difference chiefly, that, as this cement is shorter than mortar, or common stucco, and dries sooner, it ought to be worked expeditiously in all cases; and, in stuccoing, it ought to be laid on by sliding the trowel upwards on it. The materials used along with this cement in building, or the ground on which it is to be laid in stuccoing, ought to be well wetted with the lime-water in the instant of laying on the cement. The lime-water is also to be used when it is necessary to moisten the cement, or when a liquid is required to facilitate the floating of the cement.

When such cement is required to be of a still finer texture, take 98 pounds of the fine sand, wet it with the lime-water, and mix it with the purified lime and the bone-ash, in the quantities and in the manner above described, with this difference only, that 15 pounds of lime, or thereabouts, are to be used instead of 14 pounds, if the greater part of the sand be as fine as Lynn sand. This may be called *fine-grained cement*. It is used in giving the last coating, or the finish, to any work intended to imitate the finer-grained stones or stucco. But it may be applied to all the uses of the *coarse-grained cement*, and in the same manner.

When, for any of the foregoing purposes of pointing, building, &c., a cement is required much cheaper and coarse-grained than either of the foregoing, then, much coarser clean sand than the foregoing coarse sand, or well washed fine rubble, is to be provided. Of this coarse sand, or rubble, take 56 pounds; of the foregoing coarse sand, 28 pounds; and of the fine sand, 14 pounds; and, after mixing these, and wetting them with the cementing liquor, in the foregoing manner, add 14 pounds, or somewhat less, of the bone-ash, mixing them together in the manner already described. When the cement is required to be white, white

sand, white lime, and the whitest bone-ash, are to be chosen. Gray sand, and gray bone-ash formed of half-burnt bones, are to be chosen to make cement gray; and any other colour of the cement is obtained, either by choosing coloured sand, or by the admixture of the necessary quantity of coloured talc in powder; or of coloured, vitreous, or metallic powders, or other durable colouring ingredients, commonly used in paint.

This cement, whether the coarse or fine-grained, is applicable in forming artificial stone, by making alternate layers of the cement and of flint, hard stone, or bricks, in moulds of the figure of the intended stone, and by exposing the masses so formed to the open air, to harden.

When such cement is required for water-fences, two-thirds of the prescribed quantity of bone-ashes are to be omitted; and, in the place thereof, an equal measure of powdered terras is to be used; and, if the sand employed be not of the coarsest sort, more terras must be added, so that the terras shall be one-sixth part of the weight of the sand.

When such a cement is required of the finest grain, or in a fluid form, so that it may be applied with a brush; flint powder, or the powder of any quartzy or hard earthy substance, may be used in the place of sand; but in a quantity smaller, in proportion as the flint or other powder is finer; so that the flint-powder, or other such powder, shall not be more than six times the weight of the lime, nor less than four times its weight. The greater the quantity of lime within these limits, the more will the cement be liable to crack by quick drying, and vice-versâ.

Where the above described sand cannot be conveniently procured, or where the sand cannot be conveniently washed and sorted, that sand which most resembles the mixture of coarse and fine sand above prescribed, may be used as directed, provided due attention be paid to the quantity of the lime, which is to be greater as the quality is finer, and vice-versâ.

Where sand cannot be easily procured, any durable stony body, or baked earth, grossly powdered, and sorted nearly to the sizes above prescribed for sand, may be used in the place of sand, measure for measure, but not weight for weight, unless such gross powder be specifically as heavy as sand.

Sand may be cleansed from every softer, lighter, and less durable matter, and from that part of the sand which is too fine, by various methods, preferable in certain circumstances to that which has been already described.

Water may be found naturally free from fixable gas, selenite, or clay; such water may, without any great inconvenience, be used in the place of the lime-water; or a lime-water sufficiently useful, may be made by various methods of mixing lime and water in the described proportions, or nearly so.

When stone-lime cannot be procured, chalk lime, or shell lime, which best resembles stone-lime in the foregoing characters of lime, may be used in the manner described, excepting that fourteen pounds and a half of chalk-lime will be required in the place of fourteen pounds of stone-lime. The proportion of lime, as prescribed above, may be increased without inconvenience, when a cement or stucco is to be applied where it is not liable to dry quickly; and, in the contrary case, this proportion may be diminished. The defect of lime, in quantity or quality, may be very advantageously supplied, by causing a considerable quantity of lime-water to soak into the work, in successive portions, and at distant intervals of time; so that the calcareous matter of the lime-water, and the matter attracted from the open air, may fill and strengthen the work.

The powder of almost every well-dried or burnt animal substance, may be used instead of bone-ash; and several earthy powders, especially the micaceous and the metallic; and the elixated ashes of divers vegetables whose earth will not burn to lime, as well as the ashes of mineral fuel, which are of the calcareous kind, but will not burn to lime, will answer the ends of bone-ash in some degree.

The quantity of bone-ash described, may be lessened without injuring the cement; in those circumstances especially, which admit the quantity of lime to be lessened, and in those wherein the cement is not liable to dry quickly. The art of remedying the defects of lime, may be advantageously practised to supply the deficiency of bone-ash, especially in building, and in making artificial stone with this cement.

As the preceding method of making mortar differs, in many particulars, from the common process, it may be useful to inquire into the causes on which this difference is founded.

When the sand contains much clay, the workmen find that the best mortar they can make must contain about one-half lime; and hence they lay it down as certain, that the best mortar is made by the composition of half sand and half lime.

But with sand requiring so great a proportion of lime as this, it will be impossible to make good cement; for it is universally allowed, that the hardness of mortar depends on the crystallization of the lime round the other materials which are mixed with it; and thus uniting the whole mass into one solid substance. But if a portion of the materials used be clay, or any other friable substance, it must be evident that, as these friable substances are not changed in one single particular by the process of being mixed up with lime and water, the mortar, of which they form a proportion, will consequently be more or less of a friable nature, in proportion to the quantity of friable substances used in the composition of the mortar. On the other hand, if mortar be composed of lime and good sand only, as the sand is a stony substance, and not in the least friable, and as the lime by perfect crystallization, becomes likewise of a stony nature, it must follow that a mass of mortar, composed of these two stony substances, will itself be a hard, solid, unfriable substance. This may account for one of the essential variations in the preceding method from that in common use, and point out the necessity of never using, in the place of sand, which is a durable stone body, the scrapings of roads, old mortar, and other rubbish, from ancient buildings, which are frequently made use of; as all of them consist more or less of muddy, soft, and minutely divided particles.

Another essential point is the nature and quality of the lime. Now, experience proves that, when lime has been long kept in heaps, or untight casks, it is reduced to the state of chalk, and becomes every day less capable of being made into good mortar; because as the goodness and durability of the mortar depends on the crystallization of the lime, and, as experiments have proved, that lime, when reduced to this chalk-like state, is always incapable of perfect crystallization, it must follow, that, as lime in this state never becomes crystallized, the mortar, of which it forms the most indispensable part, will necessarily be very imperfect; that is to say, it will never become a solid stony substance; a circumstance absolutely required in the formation of good durable mortar. These are the two principal ingredients in the formation of mortar; but, as water is also necessary, it may be useful to point out that which is the fittest for this purpose; the best is rain-water, river-water the second, land-water the next, and spring-water last.

The ruins of the ancient Roman buildings are found to cohere so strongly, as to have caused an opinion, that their constructors were acquainted with some kind of mortar, which,

in comparison with ours, might justly be called *cement:* and that, to our want of knowledge of the materials they used, is owing the great inferiority of modern buildings in their durability. But a proper attention to the above particulars would soon show, that the durability of the ancient edifices depended on the manner of preparing their mortar more than on the nature of the materials used. The following observations will, we think, prove this beyond a possibility of doubt.

Lime, which has been slaked and mixed with sand, becomes hard and consistent when dry, by a process similar to that which produces natural *stalactites* in caverns. These are always formed by water dropping from the roof. But, when the small drop of water comes to be exposed to the air, the calcareous matter contained in it begins to attract carbonic acid from the atmosphere. In proportion as it does so, it also begins to separate from the water, and to re-assume its native form of lime-stone or marble. When the calcareous matter is perfectly crystallized in this manner, it is to all intents and purposes lime-stone, or marble of the same consistence as before. If lime, in a caustic state, be mixed with water, part of the lime will be dissolved, and will also begin to crystallize. The water which parted with the crystallized lime will then begin to act upon the remainder, which it could not dissolve before; and thus the process will continue, either till the lime be all reduced to an *effete* or crystalline state, or something hinders the action of the water upon it. It is this crystallization which is observed by the workmen when a heap of lime is mixed with water, and left for some time to macerate. A hard crust is formed upon the surface, which is ignorantly called *frosting*, though it takes place in summer as well as in winter. If, therefore, the hardness of the lime, or its becoming a cement, depends entirely upon the formation of its crystals, it is evident that the perfection of the cement must depend upon the perfection of the crystals, and the hardness of the matters which are entangled among them.

The additional substances used in the making of mortar, such as sand, brick-dust, or the like, serve only for a purpose similar to what is answered by sticks put into a vessel full of any saline solution; namely, to afford the crystals an opportunity of fastening themselves upon a nucleus. If, therefore, the matter interposed between the crystals of the lime is of a friable, brittle nature, such as brick-dust or chalk, the mortar will be of a weak and imperfect kind; but, when the particles are hard, angular, and very difficult to be broken, such as those of river or pit sand, the mortar turns out exceedingly good and strong. That the crystallization may be the more perfect, a large quantity of water should be used, the ingredients be perfectly mixed together, and the drying be as slow as possible. An attention to these particulars, and to the quality of bricks and stones, would make the buildings of the moderns equally durable with those of the ancients. In the Roman works, the great thickness of the walls necessarily required a vast length of time to dry. The middle of them was composed of pebbles thrown in at random, and which evidently had thin mortar poured in among them. Thus a great quantity of the lime would be dissolved, and the crystallization performed in the most perfect manner. The indefatigable pains and perseverance for which the Romans were so remarkable in all their undertakings, leave no room to doubt that they would take care to have the ingredients mixed together as well as possible. The consequence of all this is, that the buildings formed in this manner are all as firm as if cut out of a solid rock; the mortar being equally hard, if not more so, than the stones themselves. *See* CEMENT, CONCRETE, GROUT.

MORTAR, HYDRAULIC, sometimes also called Roman cement is the composition used in walls under, or exposed to, the action of water, such as those of harbours, docks, &c. The material best adapted to the manufacture of hydraulic mortar is the poorer sorts of limestone, such as contain from 8 to 25 per cent. of foreign matter, in silica, magnesia, alumina, &c. These, when pulverized, absorb water without swelling up, or heating, as a richer lime does, and though calcined, do not slake when moistened, but makes a paste which hardens in a few days *under* water, though in the air it never acquires much solidity. These facts were discovered by Smeaton.

The following analyses of different hydraulic limestones, by Berthier, is given by Dr. Ure in his Dict. of Arts and Manufactures.

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
A. *Analyses of limestones.*					
Carbonate of lime	97·0	98·5	74·5	76·5	80·0
Carbonate of magnesia	2·0	—	23·0	3·0	1·5
Carbonate of protoxide of iron	—	—	—	3·0	—
Carbonate of manganese	—	—	—	1·5	—
Silica and alumina / Oxide of iron	1·0	1·5	1·2	15.2	18.0
	100·0	100·0	100·0	100·0	100·0
B. *Analyses of the burnt lime.*					
Lime	96·4	97·2	78·0	68·3	70·0
Magnesia	1·8	—	20·0	2·0	1·0
Alumina	1·8	2·8	2·0	24·0	29·0
Oxide of Iron	—	—	—	5·7	—
	100·0	100.0	100·0	100·0	100·0

"No. 1, is from the fresh-water lime formation of Chateau Landon, near Nemours; No. 2, the large-grained limestone of Paris; both of these afford a fat lime when burnt. Delormite affords a pretty fat lime, though it contains 42 per cent. of carbonate of magnesia; No. 3, is a limestone from the neighbourhood of Paris, which yields a poor lime, possessing no hydraulic property; No 4, is the secondary limestone of Metz; No. 5, is the lime marl of Senonches, near Dreux; both the latter have the property of hardening under water, particularly the last, which is much used at Paris on this account."

All good hydraulic mortars must contain alumina and silica; the oxides of iron and manganese, at one time considered essential, are rather prejudicial ingredients. By adding silica and alumina, or merely the former, in certain circumstances, to fat lime, a water-cement may be artificially formed; as also adding to lime any of the following native productions, which contain silicates; puzzolana, trass or tarras, pumice-stone, basalt-tuff, slate-clay. Puzzolana is a volcanic product, which forms hills of considerable extent to the south-west of the Appenines, in the district of Rome, the Pontine marshes, Viterbo, Bolsena, and in the Neapolitan region of Puzzuola, whence the name. A similar volcanic tufar is found in many other parts of the world. According to Berthier, the Italian puzzolana consists of 44·5 silica; 15·0 alumina; 8·8 lime; 4·7 magnesia; 1·4 potash; 4·1 soda; 12 oxides of iron and titanium; 9·2 water; in 100 parts.

The tufa stone, which when ground forms trass, is composed of 57·0 silica, 16 0 clay, 2·6 lime, 1·0 magnesia, 7·0 potash, 1·0 soda, 5 oxides of iron and titanium, 9·6 water. This tuff is found abundantly filling up valleys in beds of 10 or 20 feet deep, in the north of Ireland, among the schistose formations upon the banks of the Rhine, and at Manheim in Bavaria.

The fatter the lime, the less of it must be added to the

ground puzzolana or trass, to form an hydraulic mortar; the mixture should be made extemporaneously, and must at any rate be kept dry till about to be applied. Sometimes a proportion of common sand mortar instead of lime is mixed with the trass. When the hydraulic cement hardens too soon, as in 12 hours, it is apt to crack; it is better when it takes 8 days to concrete. Through the agency of water, silicates of lime, alumina, (magnesia,) and oxide of iron, are formed, which assume a stony hardness.

Beside the above two volcanic products, other native earthy compounds are used in making water cements. To this head belong all limestones which contain from 20 to 30 per cent. of clay and silica. By gentle calcination, a portion of the carbonic acid is expelled, and a little lime is combined with the clay, while a silicate of clay and lime results, associated with lime in a subcarbonated state. A lime-marl containing less clay will bear a stronger calcining heat without prejudice to its qualities as a hydraulic cement; but much also depends upon the proportions of silica present, and the physical structure of all the constituents."

In England, what is commonly called *cement-stone*, is the substance generally used for making this kind of mortar. It is found in great abundance on the coasts of Kent, in the isles of Sheppey and Thanet, and various other places. The stones vary in size from that of a fist to a man's head, are of a yellow-gray or brown colour, interspersed with veins of talc spar. Their specific gravity is 2.59.

The following analyses of several cement-stones, and of the cement made with them, is taken from the works of Berthier, Davy, and others—

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
A. *Constituents of the cement stones.*					
Carbonate of lime	65.7	61.6	—	82.9	63.8
— magnesia	0.5	—	—	—	1.5
— protoxide of iron	6.0	6.0	—	4.3	11.6
— manganese	1.6	—	—		
Silica	18.0	15.0	—	13.0	14.0
Alumina or clay	6.6	4.8	—	trace.	5.7
Oxide of iron	—	3.0	—	—	—
Water	1.2	6.6	—	—	3.4
B. *Constituents of the cement.*					
Lime	55.4	54.0	55.0	—	56.6
Magnesia	—	—	—	—	1.1
Alumina or clay	36.0	31.0	38.0	—	21.0
Oxide of iron	8.6	15.0	13.0	—	13.7

The stones are in this country calcined in kilns, ground, sifted, and packed in casks. The colour of the powder is a dark brown, with a tinge of red. It absorbs very little water when made into paste, and soon hardens. Immediately before using, it is mixed with sharp sand in various proportions.

This composition is employed in all marine and river-embankments, in the footings of walls in damp situations, and in various other purposes to which common mortar is unsuited.

Mortar, *Mixing, Blending, and Beating of;* M. Felibien observes, that the ancient masons were so very scrupulous in the process of properly mixing and blending the materials in the making of mortar, that the Greeks kept ten men constantly employed, for a long space of time, to each bason; this rendered the mortar of such prodigious hardness, that Vitruvius tells us the pieces of plaster falling off from old walls, served to make tables. Felibien adds, that it was a maxim among old masons to their labourers, that they should dilute it with the sweat of their brow, i. e., labour at it a long time instead of drowning it with water to have done the sooner.

In modern practice, when the buildings are of considerable magnitude, the mortar is usually ground in a mill; but whichever way made, it may be laid down as a fixed rule, that the more labour there is bestowed on the mixing and thoroughly blending the mortar, the harder and better will it be, and, as a necessary consequence also, so much more perfect will be the work in which it is used.

The following excellent observations on the advantages of *beating* mortar, are taken from Mr. Weale's useful little work, "Dictionary of Terms of Arts."

"Mortar contained in a mould may be beaten or rammed in the manner of pisé, 'a mode of building formerly in use, whereby walls were formed by ramming and beating down earth, clay, &c., between upright planks,' and acquires by that means great compactness; but an increase of resistance does not always result from it.

"In order that any material be beaten with effect, it is necessary that it should possess a certain degree of consistency, which is a mean between complete pulverulence and that state of ductility which constitutes a firm paste. No compression is possible, when the material escapes from under the rammer; and this is still practised by the builders in pisé, who never employ any but earth slightly moistened. Mortar may always be prepared in this way, leaving it, after it has been worked in the ordinary manner, to undergo desiccation to a proper extent.

"The successive approximation of the particles of the compressed material to one another, necessarily determines a foliated structure, which, though it may not be perceived, is nevertheless real. Analogy will lead to the conclusion, that in every possible case, a body thus formed ought to oppose a greater resistance to a tractile force, in proportion as its direction forms a smaller angle with the plane of the laminæ; however, experience shows that this in general does not take place. The following has been determined in this respect:—

"1st. Beating has the effect of augmenting the absolute resistance of mortars of rich limes and pure sand in every case, but in an unequal manner. The greatest resistance assumes a direction perpendicular to the planes of the laminæ, when the mortars are buried in a damp soil immediately after their fabrication. It remains parallel to these same planes, when the mortars have been exposed to the atmospheric influence.

"2nd. The effect of beating is not constantly useful to mortars of hydraulic or eminently hydraulic limes, and calcareous or quartose sands or powders, except in the case when these mortars are used under a damp soil. The greatest resistance is then in a direction perpendicular to the planes of these laminæ, as with the mortars of rich limes; but in the air the superiority of the mortars which have been beaten, over those which have not, is only exhibited in one direction, and that is parallel to the plane of the laminæ.

"3rd. Beating becomes injurious in every case, when the hydrates of the hydraulic or eminently hydraulic limes are employed without admixture, and subjected to the influence of a damp soil; and is favourable to it only in the direction parallel to the laminæ, when the stuff dries in the air."

Mortar, White, used in plastering the walls and ceilings, is made of ox or cow's hair mixed with lime and water, without any sand. The common method of making this mortar, is one bushel of hair to six bushels of lime.

Mortar, used in making water-courses, cisterns, &c., is made of lime and hogs' grease, sometimes mixed with the

juice of figs, and sometimes with liquid pitch; after application, it is washed over with linseed oil.

For this purpose, mortar made of terras, puzzolana, tile-dust, or cinders, is mixed and prepared in the same manner as common mortar: only that these ingredients are mixed with lime instead of sand, in a due proportion, which is about half and half. The lime should be made of shells, or marble; and in works which are sometimes dry and sometimes wet, instead of terras, which is very dear, tile-dust or cinder-dust may be used.

Mortar, for sun-dials on walls, or for tablets to write on, may be made of lime and sand, tempered with linseed oil; or, for want of that, with skimmed milk. This will grow to the hardness of stone. For buildings, one part of washed soap-ashes, mixed with another of lime and sand make a very durable mortar.

MORTAR MILL, a machine contrived by Mr. Supple, but since much improved by others, for the purpose of saving labour, and more effectually mixing the ingredients in making mortar.

MORTISE, or Mortice, (from the French, *mortoise*, perhaps derived from *mordeo*, to bite, or pinch,) in carpentry and joinery, an excavation recessed within the surface of a piece of timber, to receive a projection called *a tenon*, left on the end of another piece, in order to fix the two together at a given angle. The sides of the mortise are generally four planes at right angles to each other, and to the surface whence the excavation is made. *See* Carpentry and Joinery.

MORTISE LOCK, a lock made to fit into a mortise cut in the style and rail to receive it.

MORTUARY, a term sometimes used to signify a burial-place.

MOSAIC, or Mosaic-Work, (from *mosaicum*, a corruption of *musaicum*, as that is of *musivum*, as it was called among the Romans: but Scaliger derives it from the Greek, *μσσα*, and imagines the name was given to this sort of work, as being very fine and ingenious; and Nebricensis is of opinion it was so called, because *ex illis picturis ornabanter musea*,) an assemblage of little pieces of glass, marble, shells, precious stones, woods, or the like, of various colours, cut square, and cemented on a ground of stucco, &c., imitating the natural colours and gradations of painting. In this sense, mosaic work includes marquetry, or inlaid work, veneering, &c. But, in its more proper and restrained sense, mosaic only takes in works of stone, metals, and glass; those of wood being distinguished by the name of *marquetry* or *inlaying*. (*See* those words.)

Others distinguish differently between mosaic and marquetry. In that properly called *mosaic*, they say the several stones are all of the same colour; and the changes and diminutions of colours and shades are made by applying different stones, one on another, but all of the same colour. Marquetry, on the contrary, consists of stones of different colours; and by these the several colours, shades, gradations, &c., are expressed.

Mosaic seems to have taken its origin from paving: the fine effect and use of pavements composed of pieces of marble of different colours,—so well joined together, as that, when dried, they might be polished, and the whole make a very beautiful and solid body, which, continually trodden upon, and washed with water, was not at all damaged,—gave the painter the hint, who soon carried the art to a much greater perfection, so as to represent foliages, masques, and other grotesque pieces, of various colours, on a ground of black or white marble. But nature not producing variety of colours enough for them in marbles, to paint all kinds of objects, they thought of counterfeiting them with glass and metals coloured.

This kind of work is supposed to have originated in the East, to have been brought from Phenicia to Greece, and thence to Rome, where it was used more especially for pavements. These pavements consisted for the most part of patterns forming borders round a central figure or device, and sometimes a group or subject; others consisted solely of patterns worked out in two or three colours, usually black, white, and red. Of all places, however, the artists of Byzantium carried this art into most extensive practice, covering both walls, pavements, and ceilings with such decoration; mosaics became indeed a very common method of enrichment in Christian churches, both in Asia and Italy. They form the most characteristic decoration of the Basilica. As a style of art, as well as a manufacture, *musive* work may be said to have arisen wholly in the era of Christianity. The material of which the mediæval mosaics are formed being chiefly glass, distinguishes them completely from the tesselated pavements of the Romans. Perhaps the nearest approach to the manufacture, is the rude inlaid work of the columns and fountains in some of the Pompeii gardens: at all events, their application is entirely peculiar to Christianity. The apex of the apse was usually reserved for this species of decoration, which still constitutes the peculiar charm of the ancient Italian churches. The solemn gigantic figures and the mysterious imagery of the mosaics, dimly seen in the darkness of the sanctuary, produce an effect denied to more elaborate specimens of art. In one most important respect they are infinitely preferable to paintings, because, both from their position and their character, they never became the objects of adoration. Usually speaking, the main figure is the Saviour in the act of judging the world; on either side, St. Peter and St. Paul: other saints are added, usually with reference to the peculiar locality. Portraits of popes or emperors connect the sacred imagery with the annals of the age. Although not governed by any definite system, yet there is a uniform course in the adaptation of the ornaments.

Mosaic work is also common in Arabian edifices, so much so indeed as to become a feature of the style. Their mosaics were principally of porcelain, and were used in the decoration of the lower part of the walls, and also for pavements. *See* Moorish Architecture.

A kind of mosaic work was common on the exteriors of some of the mediæval churches of Italy, as the Duomo at Pisa, where the walls of the façade are decorated with a sort of pattern in black and white colours, brilliant reds and blues being interspersed occasionally. Another instance of external decoration in mosaic is to be seen in the façade of St. Mark's, Venice.

Pictures in mosaic, properly so termed, and which are of comparatively recent introduction, differ from the above in being merely copies or fac-similes of paintings, approaching in appearance as nearly to pictures as possible. This style of mosaic work dates only from the commencement of the seventeenth century. The tints are graduated off from light to darker shades by using an indefinite number of very small pieces of glass of various intensities of colour, so placed that those pieces which are contiguous exhibit scarcely any perceptible difference to the eye. In the more ancient mosaics the tints are not blended one into the other, but kept quite distinct, the outlines being hard, and the joints between the tesseræ plainly visible. In these examples there is no attempt at making pictures; they are treated in a conventional manner, so that such features are to be considered as characteristic proprieties rather than defects.

Florentine work may also be added to the list of mosaics:

it is employed principally in the inlaying of marble slabs for furniture, and decorative work upon a moderate scale.

One description of mosaic work is that of introducing, along with the finest marbles, the richest of precious stones, as lapis lazuli, agates, cornelians, emeralds, turquoises, &c. The practice of making mosaics with coloured glass and metals is now little in use, though of surprising lustre and durability; but that of marbles alone is in common use; the mosaic in precious stones being so very dear, that the few workmen who apply themselves to it, make little else but petty works, as ornaments for altar-pieces, tables for rich cabinets, &c.

MOSQUE, (from the Arabic, *Maschiad*, or *Medsched*, and intermediately the Spanish and Portuguese *Mezquita* and *Masqueta*,) a Mohammedan place of worship, the distinctive marks of which are generally cupolas and minarets. Internally they exhibit nothing remarkable as to plan or accommodation, forming merely a large hall or apartment, without any seats or other fittings-up, and with no other decoration than that of pavements and carpets, or arabesques and mosaics on the walls. In regard to these latter, some of the mosques at Cairo are highly embellished. Although more famed than any other, the mosque at Santa Sophia at Constantinople exhibits nothing of Mohammedan or Arabian architecture, but was originally built as a church, and is in the Byzantine style.

All mosques are square buildings, generally constructed of stone. Before the chief gate there is a square court paved with white marble; and low galleries round it, whose roof is supported by marble pillars. In these galleries the Turks wash themselves before they go into the mosque. In each mosque there is a great number of lamps; and between these hang many crystal rings, ostriches eggs, and other curiosities, which, when the lamps are lighted, make a fine show. As it is not lawful to enter the mosque with stockings on, the pavements are covered with pieces of stuff sewed together, each being wide enough to hold a row of men kneeling, sitting, or prostrate. The women are not allowed to enter the mosque, but stay in the porches without. About every mosque there are six high towers, called *minarets*, each of which has three little open galleries, one above another: these towers, as well as the mosques, are covered with lead, and adorned with gilding and other ornaments, and from thence, instead of a bell, the people are called to prayers by certain officers appointed for that purpose. Most of the mosques have a kind of hospital belonging to them, in which travellers of what religion soever, are entertained three days. Each mosque has also a place called *tarbe*, which is the burying-place of its founders; within which is a tomb six or seven feet long, covered with green velvet or satin; at the ends of which are two tapers, and round it several seats for those who read the koran and pray for the souls of the deceased. *See* MOORISH ARCHITECTURE.

MOTION, *Local*, a continued or successive change of place.

MOTION, *Absolute*, the change of place in a moving body, independent of any other motion.

MOVEMENT, (from the French,) in architecture, a term used by some writers to express the rise and fall, the advance and recess, with other diversities of form, in the different parts of a building.

MOULD, *Glaziers'*. The glaziers have two kinds of moulds: in one they cast the lead into long rods, or canes, fit to be drawn through the vice, in which the grooves are formed; this they sometimes call *ingot-mould*. In the other, they mould those little pieces of lead, a line thick, and two lines broad, which are fastened to the iron bars of casements, &c.

MOULD, among masons, a piece of hard wood, or iron, hollowed on the edge, answerable to the contours of the mouldings or cornices, &c., to be formed. It is otherwise called *a caliber*; and is made to a section of the stone intended to be cut. The ends, or heading-joints, being formed as in a cornice by means of the mould, the intermediate parts are wrought down by straight-edges, or circular templets, according as the work is straight or circular upon the plan.

When the intended surface is required to be very exact, a reverse mould is used, in order to prove the work, by applying the mould in a transverse direction to the arrises.

MOULDS, among plumbers, the tables on which they cast their sheets of lead; sometimes called simply *tables*. Besides these, they have others, in which they cast pipes, without soldering.

MOULDINGS, in architecture, prismatic or annular solids, formed by plane and curved surfaces, and employed as ornaments.

All parallel sections of straight mouldings, all the sections of annular mouldings, made by a plane at the same inclination to the axis, and, in general, all sections of mouldings made by a plane perpendicular to any one of the arrises, are similar figures. Mouldings are divided into two classes, or kinds; Grecian and Roman.

Grecian mouldings are formed of some conic section, as a portion of the ellipsis or hyperbola; and sometimes even of a straight line, in the form of a chamfer.

Roman mouldings have their sections composed of the arcs of circles, the same moulding having the same curvature throughout.

In both Grecian and Roman mouldings, their species is determined by the position of their extremities, or the circumstance of their being concave or convex: if the section be a semicircle projecting from a vertical diameter, the moulding is called an *astragal*, *bead*, or *torus*.

If the moulding be convex, and its section the quarter of a circle, or less, and if one extremity project beyond the other, that is, approach nearer to the eye than the other, it is termed a *Roman ovolo*; and if this Roman ovolo project equal to its height, and the portion employed be the quadrant of a circle, it is then called a *quarter-round*. If the section of a moulding be concave, but in all other respects the same as the last, it is denominated a *cavetto*.

If the section of a moulding be partly concave and partly straight, the straight part being vertical and a tangent to the concave part, and the concavity equal to, or less than the quadrant of a circle, the moulding is denominated an *apophygé*, *scape*, *spring*, or *congé*: this is used in the Ionic and Corinthian orders for joining the bottom of the shaft to the base, as well as to connect the top of the fillet to the shaft under the astragal.

If the section be one part concave and the other convex, and so joined as to have the same tangent, the moulding is named a *cymatium*; but Vitruvius calls all crowning or upper members cymatiums, whether they resemble the one now described or not.

If the upper projecting part of the cymatium be a concave, it is called a *sima-recta*; this is generally the crowning member of cornices, but is seldom found in other situations except on pedestals or altars.

If the upper projecting part of the cymatium be convex, it is called a *sima-reversa*, and is the smallest in any composition of mouldings, its office being to separate the larger members. Though seldom used as a crowning member of cornices, it is frequently employed with a small fillet over it, as the upper member of architraves, capitals, and imposts.

If the convex part of a moulding recede and meet a horizontal surface, the recess formed by the convexity and the horizontal surface is termed a *quirk*.

If the section of the moulding be a convex conic section, the intermediate part of the curve projecting only a small distance from the greatest projecting extremity, and the tangent to the curve at the receding extremity meeting a horizontal line, produced forward without the curve at the upper extremity, the moulding is called an *ovolo*. This is generally employed above the eye, as a crowning member in the Grecian Doric. Ovolos may be used in the same composition of different sizes; it is sometimes cut into egg-and-tongue, or egg-and-dart, when it is termed *echinus*. It is employed instead of a torus in the base of the monument of Lysicrates, at Athens. The contours of ovolos are generally elliptical or hyperbolical curves. These curves can be regulated to any degree of quickness or flatness; the parabola can also be drawn under these conditions, but its curvature, being of the intermediate species, does not afford the variety of change admitted by the other two.

If the section be a concave semi-ellipsis, having its conjugate diameter such that the one may unite the extremities of its projections, and the other diameter parallel to the horizon, the moulding is termed a *scotia*. This is always employed below the level of the eye, between two tori. One extremity has generally a greater projection than the other, the greater projection being nearest to the level of the eye.

If the section of the moulding be the two sides of a right angle, the one vertical, and the other, of course, horizontal, it is termed a *fillet*, *band*, or *corona*. A fillet is the smallest rectangular member in any composition of mouldings. Its altitude is generally equal to its projection; its purpose is to separate two principal members, and it is used in all situations under such circumstances. The corona is the principal member of a cornice. The facia is a principal member in an architrave as to height, but its projection is not more than that of a fillet, unless it be the lower facia, where the soffit is the whole breadth of the top, or sometimes even of the bottom of the shaft. Mouldings are either plain, or enriched with eggs, and with foliage displayed in a variety of forms; some enrichments are peculiar to certain forms, as egg-and-anchors, or egg-and-tongue, to the ovolo.

Mouldings in assemblage are used in the formation of cornices, architraves, bases, capitals, &c. *See* Apophyge, Cavetto, Cymatium, Echinus, Ovolo, Quarter-Round, Scape, Scotia, Sima-Recta, Sima-Reversa.

Plate I.—*Figure* 1, a quarter-round.

Figure 2, a cavetto, being exactly the reverse of the last figure; both being the quarter of a circle.

Figure 3, the sima-reversa, composed of two quadrants of a circle.

Figure 4, the sima-recta, being the reverse of the sima-reversa.

Figure 5, a torus, which is a semicircle described upon a vertical diameter.

Figure 6, a scotia, which, projecting equally at each extremity, occasions the contour to be exactly the reverse of the torus.

The following are the methods of describing Roman mouldings, where the projections and heights are unequal; the extremities of the moulding being given.

Figure 7.—*To describe the Roman ovolo.* Let A be the upper extremity, and B the lower; take the vertical line or height; from B, with that radius, describe an arc; from A, with the same radius, describe another arc, cutting the former at *c*; then from *c*, with the same radius, describe the arc A B, which will be the contour required.

Figure 8.—*To describe the cavetto.* With a radius equal to the height of the moulding, from the points A and B describe arcs, cutting each other in *c*; then from *c*, with the same radius, describe the arc A B, which will give the contour of the cavetto required.

Figure 9.—*To describe a sima-reversa, that shall touch a straight line at the points of contrary flexure.* Join the projections A and B by the straight line A B; bisect A B in D; draw the tangent E D, parallel to a line given in position; through D draw *c c*, perpendicular to E D; bisect A D by a perpendicular, *g c*; from the intersection *c*, describe the arc A *g* D; make D *c* equal to *c'*; from the lower point *c'*, describe the arc D B: then the curve of contrary flexure, A D B, will be the sima-reversa required.

Figure 10.—*To describe a sima-recta to touch a straight line at the points of contrary flexure, parallel to a line given in position.* Join the points of projection A and B; bisect A B in D, and draw the line D E parallel to the line given in position; bisect A D by the perpendicular *c g*; from *c*, with the radius *c* D, describe the arc A D; make D *c'* equal to D *c*, and from the other point *c'* within, describe D B: then A D B is the sima-recta required.

Figure 11.—*To describe the Grecian ovolo, two tangents being given, as also their points of contact.* Let A E and E B be the tangents; A and B the points of contact; complete the parallelogram B E A *d*; produce B *d* to *c*, and make *d c* equal to *d* B; divide E A and *d* A each into the same number of equal parts; through the points of division in E A, draw lines to B; draw lines to *c* through the corresponding points in *d* A, to meet the corresponding lines drawn to B; and the intersections will be in the curve of an ellipsis. The upper part, A Q, is a continuation of the same curve.

The same directions extend to *Figures* 12, 13, 14: but the following difference may be observed:

In *Figure* 11, the tangent B E is regulated by taking the point E in the middle of A D. In *Figure* 12, the point E is one-third of A D from the bottom. In *Figure* 13, in the middle of A D, as in *Figure* 11. In *Figure* 14, the point E is one-third of A D, from A. Then, according as the tangent is lower or higher, the curve will be quicker or flatter at the same projection: so that, among these curves, *Figure* 12 is the boldest, and *Figure* 14 the flattest.

When E B and A E are nearly equal, the moulding is the boldest of any, taking D E at the same height; but when the projection is very great, or very small, the moulding is extremely flat.

Figure 15.—*The same data being given, to describe the Grecian ovolo; supposing the point of contact,* B, *to be the extremity of one of the axes.* Draw B K perpendicular to E B; also P *c* perpendicular to B K, for the other axis, so that the point P may be above A; then E B and P *c* will be parallel. To find the major axis: from A, with the distance B *c*, describe an arc, cutting P *c* at F; draw A F, and produce it to meet B K in I; make *c* P equal to A I; then with *c* P, half the major axis, and *c* B, half the minor axis, describe the curve B A P Q, which will be the moulding required.

This method forms the most beautiful moulding of any; the curvature being continually increased from the point B to P.

The same description applies to *Figures* 16 and 17. With regard to the quirk at the point Q, it will be more or less, as the point A is more or less distant from Q.

The quantity of curvature depends upon the angle E B D; so that when the angle E B D is less, the curvature will be greater.

For a description of mouldings employed in Norman and Gothic Architecture, we must refer the reader to the subjects treated of under these respective titles.

MOULDING-PLANE. *See* PLANE, and TOOLS.

MOULDINGS, *Raking*. *See* RAKING MOULDINGS.

MOUTH, in the courts of princes, an apartment consisting of several rooms, as offices, kitchens, &c., where the meat intended for the first tables is dressed by itself.

MULLIONS, in pointed architecture, all those parts of windows which divide the light into compartments, and are either curved or straight.

Vertical mullions are called *munnions;* and those which run horizontally are called *transoms*. The whole of the mullions of a window above the springing of the arch are called the *head-work*.

MULTILATERAL, (from the Latin, *multus*, many, and *latera*, sides) in geometry, a term applied to figures which have more than four sides or angles, more usually called *polygons*.

MULTIPLICATION, (from the Latin, *multiplicatio*) the act of multiplying, or increasing a number. Accurately speaking, in every multiplication, the multiplier must always be considered as a number; and it is easy to conceive a quantity of any kind multiplied by a number. But to talk of a pound multiplied by a pound, a debt by a debt, or a line by a line, &c., is unintelligible. However, by analogy, in the application of algebra to geometry, we meet with such expressions, and nothing is more common than to find A B × B C, to denote the rectangle A B C D, the length of which is A B, and the breadth B C. But this is only to be understood by analogy; because, if the number expressing the measure of the side A B were multiplied by the number expressing the measure of B C, the product would express the measure of A B C D.

The sign of multiplication mostly used among algebraists, is ×. But the Germans, after Leibnitz, only make use of a point placed between the quantities multiplying each other, thus: $a . b$ is the same as $a \times b$; and A B . B C, the same as A B × B C, or the rectangle of A B into B C.

MUNIMENT-HOUSE, a small strong apartment in cathedral and collegiate churches, castles, colleges, or the like, destined for keeping the seal, evidences, charters, &c., of such church, colleges, &c., called *muniments*, or *miniments*.

MUNNIONS, see MULLIONS.

MURAL, (from the Latin *murus*) something belonging to a wall. Thus mural monument, arch, and columns, *i. e.* attached to the wall.

MURAL ARCH, a wall, or walled arch, placed exactly in the plane of the meridian, *i. e.* upon the meridian line, for the fixing of a large quadrant, sextant, or other instrument, to observe the meridian altitudes, &c., of the heavenly bodies. Tycho Brahe was the first who used a mural arch in his observations; after him, Helvelius, Flamsteed, De la Hire, &c., used the same means.

MUSES, (from the Greek *μουσαι*) fabulous divinities of the ancient heathens, who were supposed to preside over the arts and sciences.

The ancients admitted of nine Muses, and made them the daughters of Jupiter and Mnemosyne, or Memory. At first, indeed, their number was but three; *viz.*, Melete, Mneme, and Aæde; Greek words, signifying *meditation*, *memory*, and *singing:* but a certain sculptor of Sicyon, according to Varro, having orders to make three statues of the three Muses for the temple of Apollo, and mistaking his instructions, made three several statues of each Muse: these however, were found so beautiful, that they were all set up in the temple; and from that time they began to reckon nine Muses; to whom Hesiod afterward gave names; *viz.* Calliope, Clio, Erato, Thalia, Melpomene, Terpsichore, Euterpe, Polyhymnia, and Urania.

Each of these was to preside over her respective art; Calliope over heroic poetry; Clio over history; Melpomene over tragedy; Thalia over comedy; Euterpe over wind-music; Urania over astronomy; Terpsichore over the harp; Erato, the lute; Polyhymnia, rhetoric.

They are painted as young, handsome, and modest; agreeably dressed, and crowned with flowers. Their usual abodes were about mount Helicon, in Bœotia, and mount Parnassus, in Phocis. Their business was to celebrate the victories of the gods, and to inspire and assist the poets; and hence the custom of invoking their aid at the beginning of a poem.

MUSEUM, (from the Greek *μουσειον*) originally signified a palace of Alexandria, which occupied at least a fourth part of the city; and was so called from its being set apart to the Muses and the sciences.

Here were lodged and entertained a great number of learned men, who were divided into companies or colleges, according to the sciences or sects of which they were professors. And to each house or college was allotted a handsome revenue. This establishment is attributed to Ptolemy Philadelphus, who fixed his library in it.

Hence the word has passed into a general denomination, and is now applied to any place set apart as a repository for things that have some immediate relation to the arts, or to the Muses.

MUTILATED CORNICE, one that is broken or discontinued.

MUTILATED ROOF, see ROOF.

MUTILATION, (from the Latin *mutilatio*, maiming) the retrenching or cutting away any part of a regular body. The word is extended to statues and buildings where any part is wanting, or the projection of any member discontinued.

MUTULE, in architecture, a part of the Doric cornice, appearing to support the corona and the superior members, formed by three vertical parallelograms at right angles, and an inclined plane which descends towards the front of the cornice, until it meets the rectangular vertical plane, the inclined plane being the soffit, and the two vertical parallel planes being at right angles to the surface of the frieze, and the vertical plane on the front parallel thereto.

Mutules had their origin from the ends of rafters in the original wooden structures, and are, therefore, properly represented with a declination towards the front of the corona; though represented by an architect of the last century with a level soffit. See DORIC ORDER.

MYLASSENSE MARMOR, in the works of the ancients, a species of marble dug near the city of Mylassense in Caria. It was of a black colour, but with an admixture of purple, not disposed in veins, but diffused through the whole mass. It was much used in building among the Romans.

MYNCHERY, the same as NUNNERY, which see.

MYRON, a celebrated statuary of Greece. He made a cow of brass, of admirable workmanship, much lauded by writers of that period

N.

NAILS (from the Saxon *nægl*) in building, &c. small metalline-spikes, serving to bind or fasten the parts together, &c.

The several kinds of nails are very numerous ; as *back-nails*, made with flat shanks to hold fast, and not open the wood. *Clamp-nails*, proper to fasten the clamps in buildings, &c. *Clasp-nails*, or *brads*, whose heads being flatted, clasp and stick into the wood, rendering the work smooth, so as to admit a plane over it : the most common in building are distinguished by the names *ten-penny*, *twenty-penny*, *two-shilling*, &c. *Clench-nails*, used by boat, barge, &c. builders, with boves or nuts, and often without : for fine work, they are made with clasp heads, or with the head beat flat on two sides. *Clout-nails*, ordinarily used for nailing on of clouts to axle-trees, are flat-headed, and iron-work is usually fixed with them. *Deck-nails* are for fastening of decks in ships, doubling of shipping, and floors laid with planks. *Dog-nails*, or *jobent-nails*, proper for fastening of hinges to doors, &c. *Flat-points* are of two kinds, *viz. long*, much used in shipping, and proper where there is occasion to draw and hold fast, yet no necessity of clenching ; and *short*, which are fortified with points, to drive into oak, or other hard wood. *Lead-nails* used to nail lead, leather, and canvass, to hard wood, are the same as *clout-nails*, dipped in lead or solder. *Port-nails*, commonly used for nailing hinges to the ports of ships. *Ribbing-nails*, used to fasten the ribbing, to keep the ribs of ships in their place in building. *Rose-nails* are drawn square in the shank, and commonly in a round tool. *Rother-nails*, chiefly used to fasten rother-irons to ships. *Scupper-nails*, much used to fasten leather and canvass to wood. *Sharp-nails*, much used, especially in the West Indies, with sharp points and flat shanks. *Sheathing-nails*, used to fasten sheathing-boards to ships : the rule for their length is, to have them full three times as long as the board is thick. *Square-nails*, of the same shape as *sharp-nails ;* chiefly used for hard wood. *Brads*, long and slender, without heads, used for thin deal work, to prevent splitting. To these may be added *tacks ;* the *smallest* serving to fasten paper to wood ; *middling*, for wool-cards and oars ; and *larger*, for upholsterers and pumps. They are distinguished by the names of *white-tacks*, *two-penny*, *three-penny*, and *four-penny*, *tacks*.

NAIL-HEAD MOULDING, a Norman moulding, so named from its appearance, which is that of a surface studded with nails or nail heads.

NAKED FLOORING, the whole assemblage, or contignation of timber-work, for supporting the boarding of a floor on which to walk. Naked flooring consists of a row of parallel joists, called *floor-joists*.

When naked flooring consists of two rows of joists, of which the upper is supported by the under row, all the joists of the upper row crossing every one of the under at right angles, the supporting or lower row are called *binding-joists ;* while the joists supported, or those of the upper row, are denominated *bridging-joists*. When the ends of binding-joists are framed into each side of a strong beam, such beam is called a *girder*. There are many curious methods of joining timbers in short lengths ; for which the reader whose curiosity inclines to investigations of this nature, may consult the subsequent part of this article, from Wallis's *Opera Mathematica*, vol. i. prop. x. chap. vi., where he will find the demonstrations relating to the strength of timbers, according to their dispositions and bearings, and where several very ingenious methods of combining timbers in the forms of squares, oblongs, equilateral triangles, and pentagons, are shown by that renowned author. Of this species of flooring, Serlio has exhibited a design. Godfrey Richards, in his *Palladio*, exhibits the diagrams of two floors of this description, executed in Somerset House, which, he says, "was a novelty in England." Notwithstanding the ingenuity of this method of construction, it has been long out of use, probably, from the general introduction of foreign timber, which furnishes any lengths requisite for the purpose of building.

All the joists in the same floor, to which the boarding is attached, should be disposed in one direction, as the heading-joints of one set of boards should never meet the edges of another : the strength of the work, however, is by no means to be sacrificed, by a wrong disposition of the joisting, in order to make the joints of the boarding parallel to each other ; symmetry of appearance being but a trifle compared to the strength of the work. Indeed the ends of the boards may be made to meet the edges of others under the bottom edge of the door in each apartment, should such a disposition be necessary.

In double naked flooring, when the binding-joists run parallel to the chimney side of the room, the joist nearest to such side ought to be placed at a distance from the breast of the chimney, equal to the breadth of the hearth, with an allowance for the brick trimmer by which the hearth is supported.

Floors are constructed by different methods, according to the bearing of the timber. When the rooms have small dimensions, the floor generally consists of single joists; when large, the framing for the support of the floor consists of two rows of beams, the lower supporting the higher : when the extent is so great, that the lower rows of beams would be too much weakened to support the upper rows and the floor for walking upon, a strong beam, called a *girder*, is introduced, so as to divide the length of the apartment; or two, three, &c., are introduced, so as to divide the length into three or four equal parts, as may be required for bearing the timber. The girders thus introduced should always be placed in the breadth or least dimension of the rectangle, or floor. The lower row of parallel beams are called *binding-joists*, and the transverse beams, which are supported by them, *bridgings* or *bridging-joists*. The binding-joists are framed into the girder, or girders, and the bridgings are notched upon the binding-joists.

Plate I. *Figure* 1.—A section of naked flooring, without binding-joists, but with a girder, into which the joists that support the flooring are framed, and the ceiling-joists into deep joists, which also support the boarding. The end of the girder is shown in No. 1, as also the sections of the ceiling-joists. No. 2 is the transverse section of the floor, showing the sections of the boarding-joists, as also the sections of the strong joists, and the sides or longitudinal directions of the ceiling-joists.

Figure 2.—A section of a double floor. No. 1, shows the longitudinal section of the binding joists, a section of the girder, and the sections of the bridging and ceiling-joists. No. 2, shows the sections of the binding-joists, and the longitudinal directions of the bridging and ceiling-joists.

When girders are extended beyond a certain length, they

acquire a degree of curvature from their weight, which in time reduces them to a concavity on the upper side, called *sagging*. To prevent this disagreeable consequence, without any intermediate support from the floor below, a strong truss, in the form of a low roof, is introduced between two equal beams, so as to make the whole discharge the weight at each extremity. To prevent the bad effects resulting from the shrinking of the timber, the truss-posts are generally constructed of iron, screwed and nutted at the ends; and to give a firmer abutment, the braces are let into a groove in each fitch or side. The abutment at each end is also made of iron, and is either screwed, nutted, and bolted through the thickness of both halves, that the braces may abut the whole dimensions of their section; or otherwise the two abutments are made in the form of an inverted wedge, where they are screwed and nutted. These modes may either be constructed with one truss-bolt in the middle, or with two, dividing the whole length into three equal parts: a straining-piece being placed in the middle, shortens the braces, and elevates them at a higher angle, so that the truss may give a more powerful resistance to the superincumbent weight. The braces may be constructed of oak, or of cast-iron; the bolts, from their nature, must be of wrought-iron.

As iron is subject to contraction and expansion, it is less eligible for the braces than wood, which is almost invariable in any degree of temperature, as to heat or cold; oak is therefore generally employed for this purpose.

Figure 3.—A longitudinal section of a truss-girder, consisting of two braces, meeting the truss-bolt in the middle.

Figure 4.—A longitudinal section of a truss-girder, divided into three parts; consisting of two braces, with a straining piece in the middle. No. 1. A longitudinal vertical section. No. 2. The upper side.

When the bearing is very great, the truss would require to be deep, to enable it to resist with greater efficacy: this construction may be as in *Figure* 5.

Figure 6.—Middle bolt.

Figure 7.—Abutment, as shown in *Figures* 3 and 4.

Figure 8.—Washers, to prevent a partial sinking of the nuts.

"*To construct the plain raftering for a floor, by joining together rafters that otherwise would not extend across the given space, so that the whole extent of the area may be perfectly level; and to estimate, by calculation, the pressure upon the whole, and upon the parts separately.*

"I. *The construction of the raftering.*—PLATE II. Let *Figure* 1 exhibit the square area, any side of which is about quadruple the length of the longest rafter: the rafters are so fitted into each other as reciprocally to support themselves. The rafters that are dovetailed into the beams laid on the wall, are cut the whole depth of the timber, into the tenon of the dovetail; the mortise for this tenon is therefore in the wall-beam. The other ends of these rafters, each of which is fitted into the wall-beams, is formed into a tenon of about half the depth of the rafter; the mortise for this tenon is therefore, in another rafter, notched to a correspondent depth, so that the upper parts of both may be flush with each other, as will also happen to the lower sides. And because the tenon is but half the depth of the wood, the rafter to which it belongs is supported by half the depth of the rafter in which is the mortise, every rafter carrying the one that is fitted into it; as this is the case throughout the whole extent of the area, they must necessarily support each other over all parts of the area: and the parts towards the middle of the area, where, from the natural flexibility of the timber, the only fear is to be apprehended, lest, by the weight above, the interior of the floor should sink down, have this disadvantage provided against, by the excavations not extending precisely to the middle of the timber, but being a little deficient towards the middle. For, as by this method the raftering will rise progressively with each joint from the exterior to the centre of the area, any small depression that, from the weight above, might take place, will not be sufficient to reduce it below the fair level throughout; the curvature produced on the whole will compensate the weight, and prevent any hollow taking place.

"*Figure* 2, exhibits the side face of one of the longer timbers; where the end tenons and mortises, at one-third and two-thirds of the whole lengths, are sufficiently well exhibited: and *Figure* 3, shows one of the shorter timbers in that view which offers the end tenons and the single mortise. The upper face of all the rafters appears very plainly from *Figure* 2.

"But since they are disposed in so compact an order in this last-named Figure, the process may be much more easily understood from a close investigation of the diagrams than it can be from any explanation.

"It is very obvious, that the four great beams laid upon the wall are the first with which we ought to begin; for we would naturally proceed from these principal beams to the secondaries or rafters. Now, if we examine these principal beams, we shall find, that into each there are dovetailed five rafters or secondaries, and these have their other ends supported by other rafters parallel to the wall-beams; and those which carry the rafters dovetailed into the wall-beams, are themselves supported by others in a transverse direction; and so on, till they arrive at the opposite wall.

"For example, the rafter *&* s has one end dovetailed into the wall-beam, but the other end is supported by the rafter *&* z; this last rafter, *&* z, has one end dovetailed into another wall-beam, but the other end, z, is supported by the rafter P Q: and the rafter U Y has one end dovetailed into the wall-beam, but the other end, Y, is carried by P Q in the same manner as *&* z: P Q is supported at P by I K, and at Q by R S: but I K and R S do also support the rafter O N, which in its turn supports the ends F, M, of the rafters F E, M L; H M L supports R X and V W; then we have determined the support of R, one end of the rafter S R; and V W supporting V, the end of the rafter V U, we come to V U supporting H G and I K: but the end, U, of the rafter V U, is supported by Y U; Y is supported by P Q, and P Q supports also *&* Z, and is itself supported by S R: but S R is supported by R X and S *&*: and thus we trace round the exterior framing, and discover the aid which these rafters reciprocally lend each other, to render the whole secure and compact. For if we follow the concatenation, we shall discover, from the slightest inspection of the diagram, the principle upon which, in regular succession, the parts conduce to give strength to the whole. In the same manner, when we begin to trace, from the centre of the framing, every rafter, A B and C D are supported by A B and E F; and also from these we trace L M, G H, and N O, reciprocally supported and giving their support; and following the others that are connected with those now named, we go on till we arrive at those which terminate, and are supported by the principal beams on the wall; as clearly appears from the plan.

"This method enables us to construct a floor scantling of this description with many, or even with few rafters; but in any other method, as in the case of an oblong differing but little from a square, we shall have to employ the following conditions:

"For example, in this same case the whole wall can be laid out, so that the rafters R S, U V, and *&* S brace, and are themselves braced; or, where the rafters *&* Z, M L, and P Q,

are braced by others, or themselves are bracers; whence the area is extended less widely, as by the paucity of the rafters it extends from wall to wall by the rafters S &c, Q P, U V, L M, R S, and Z &c; but so long as there is occasion for only four rafters, the construction may be similar to *Figure* 4, or even of only three, as in *Figure* 5, which is the most simple form of any.

"But even if there were occasion (*Figure* 1) the rafters X R, W V, (and the remaining shorter ones that terminate in the wall) might be produced to an equal length with the others, and would support the corresponding rafters parallel to the principal beams, in which are fixed X R, V W, and Y U; and thus the ends of these, continued, would either be supported by the beams lying upon the wall, or even by others, as far as the area is extended, parallel to M L and P Q; and so on, to any distance that the work may require. For in the continued area, the number of the rafters being augmented, the weight may be increased to as much as the walls are able to sustain; for rafters may be found that will not give way, nor break under any weight the walls will carry.

"But although we are able to proceed safely in this regular proportion, it is from calculation that we must discover the weight which such a piece of framing will bear. For if it appears, from the quantity of weight laid on, that the rafters will everywhere bear it, then as much of the weight as any situation, or place of the area, has laid upon it, being in like proportion also laid on another, it becomes regularly and fairly distributed over the whole; and hence is the best judgment formed of what may safely be done. The calculation when the number of timbers is few, is pretty easy; but more laborious where there are many.

"But I shall show by what method this may be effected; each rafter of the continued framing, joined to its fellow, is subjected to this calculation; perplexed in a manner, it is true, from their number, but producing the result much more rapidly where there are few rafters.

"*Calculation accommodated to the raftering now explained.*

"That the calculation delivered in the following synopsis may be more clearly understood, it is to be observed, as is indeed sufficiently indicated to the eye, that some of the rafters are longer than others; and that the longer are about one and a half of the shorter ones. On this account we shall designate the weight of each of the longer rafters by T; and that of each of the shorter by $\frac{2}{3}$ T.

"But the weight upon every one of the joints of the rafters, will be indicated by the letter written on that joint in the diagram.

"Let it be moreover observed, since it may tend to elucidate our subject, that there are always four points which, on account of their similarity of situation in regard to the whole framing, equally determine the weight laid on them: these we shall always designate by the same marks, lest the number of the symbols should increase, and the calculation be thereby perplexed. Hence we shall have four A's, similarly situated and equally loaded, the same number of B's, and so on with the others. Whence it will be, for example (to No. 2, or the following equation) $B = \frac{1}{2}T + \frac{2}{3}C + \frac{1}{3}A$; in the same way, also, if the point, B, of the rafter, A B, thus subjected, be said to sustain as much weight as is laid upon it; besides that firmness which is necessary to prevent the wood giving way from the weight it carries, as this equation does not involve it; so much then is $\frac{1}{2}$ T (one half of the weight lying on A B, one of the longer rafters); then $\frac{2}{3}$ C (two-thirds of the weight of the same A B, situated on the point C; seeing that in C, A, it is understood to be cut in three different ways by the points); then $\frac{1}{3}$ A (one-third of the weight of the same rafter A B is placed in A.) Whence also there will be (to No. 21.) $W = \frac{1}{3}T + \frac{1}{2}V$: here we discover that in the point W of the rafter L M, the weight placed upon it is as much as is $\frac{1}{3}$ T (one-half of the weight of the short rafter, which is also a third of the longer one); then $\frac{1}{2}$ V (one-half of the weight, which is placed over the middle point, V, of the rafter so lying upon this one); which, by similarity, enables us to obtain 25 in the first equations.

"The equation 26, and those which follow, are derived from the preceding, which we have cited by numbers written for those equations; whence the manner of the whole process may be more clearly deduced. These partly serve for abbreviating fractions, as often as the numerators and denominators may be divided by the same common measure: but their most essential use is, to reduce and explain the preceding equations, by substituting the value of every individual symbol, and explaining it by other marks, on which account, as often as any symbols are expunged, the number of those which remain is sensibly lessened, till at last some one of the symbols unknown from the beginning, is expressed by the known quantity T, the weight of the longer rafters, considered simply by itself; and then, by examining every step of the preceding equations, the values of the remaining symbols are also found first of the unknown weights.

"For example, when there is (No. 1.) $A = \frac{1}{2}T + \frac{2}{3}A + \frac{1}{3}C$ (on account of A being found on both sides of the equation) it is manifest, that on taking away $\frac{2}{3}$ A on both sides, there will remain $\frac{1}{3}A = \frac{1}{2}T + \frac{1}{3}C$; that is (by multiplying both sides by 3) $A = \frac{3}{2}T + C$; and thus we have (No. 26.) this equation, as derived from the first equation (No. 1.) and which we have cited.

"By similarity, since it may be (No. 2.) $B = \frac{1}{2}T + \frac{2}{3}C + \frac{1}{3}A$; and (by No. 26) it may be $A = \frac{3}{2}T + C$; and so $\frac{1}{3}A = \frac{1}{2}T + \frac{1}{3}C$; B will be $(= \frac{1}{2}T + \frac{2}{3}C + \frac{1}{3}A = \frac{1}{2}T + \frac{2}{3}C + \frac{1}{2}T + \frac{1}{3}C) = T + C$. Whence we have this equation ($B = T + C$) No. 27, as derived from No. 2 and 26. And in like manner for the others.

"But, at no time, as we have said, is there more than the abbreviation of the fraction, as a reduction to less results by a common divisor. As when (No. 64) we have

$$H = \frac{6912\,T + 672\,G + 552\,I + 2790}{2907 = 3 \times 969};$$

and then all the members can be divided by 3; we have No. 65 (as derived from No. 64) the equation $H = \frac{2304\,T + 224\,G \times 184\,I + 930}{969}$; and so for others.

"But as all these reductions and abbreviations of the equations are deduced singly, as we have deduced these few, we shall here briefly express them all in a continued synopsis; indicating those antecedent equations upon which the other depend.

"SYNOPSIS OF THIS CALCULATION.—*Figure* 1.

No.

1. $A = \frac{1}{2}T + \frac{2}{3}A + \frac{1}{3}C$.
2. $B = \frac{1}{2}T + \frac{2}{3}C + \frac{1}{3}A$.
3. $C = \frac{1}{2}T + \frac{2}{3}G + \frac{1}{3}I$.
4. $D = \frac{1}{2}T + \frac{2}{3}I + \frac{1}{3}G$.
5. $E = \frac{1}{2}T + \frac{2}{3}B + \frac{1}{3}D$.
6. $F = \frac{1}{2}T + \frac{2}{3}D + \frac{1}{3}B$.
7. $G = \frac{1}{2}T + \frac{2}{3}E + \frac{1}{3}L$.
8. $H = \frac{1}{2}T + \frac{2}{3}L + \frac{1}{3}E$.
9. $I = \frac{1}{2}T + \frac{2}{3}N + \frac{1}{3}P$.
10. $K = \frac{1}{2}T + \frac{2}{3}P + \frac{1}{3}N$.
11. $L = \frac{1}{2}T + \frac{2}{3}W + \frac{1}{3}X$.

No.

12. $M = \frac{1}{2}T + \frac{2}{3}X + \frac{1}{3}W.$
13. $N = \frac{1}{2}T + \frac{2}{3}F + \frac{1}{3}M.$
14. $O = \frac{1}{2}T + \frac{2}{3}M + \frac{1}{3}F.$
15. $P = \frac{1}{2}T + \frac{2}{3}Y + \frac{1}{3}Z.$
16. $Q = \frac{1}{2}T + \frac{2}{3}Z + \frac{1}{3}Y.$
17. $R = \frac{1}{2}T + \frac{2}{3}O + \frac{1}{3}Q.$
18. $S = \frac{1}{2}T + \frac{2}{3}Q + \frac{1}{3}O.$
19. $V = \frac{1}{2}T + \frac{2}{3}H + \frac{1}{3}K.$
20. $U = \frac{1}{2}T + \frac{2}{3}K + \frac{1}{3}H.$
21. $W = \frac{1}{3}T + \frac{1}{2}V.$
22. $X = \frac{1}{3}T + \frac{1}{2}R.$
23. $Y = \frac{1}{3}T + \frac{1}{2}U.$
24. $Z = \frac{1}{3}T + \frac{1}{2}\&$
25. $\& = \frac{1}{3}T + \frac{1}{2}S.$
26. $A = \frac{3}{2}T + C$, by No. 1.
27. $B = T + C$, by 2, 26.
28. $C = \frac{3}{2}T + \frac{2}{3}G + \frac{1}{3}I$, by 27, 3.
29. $E = \frac{15T + 5G + 4I}{9}$, by 5, 28, 4.
30. $F = \frac{12T + 4G + 5I}{9}$, by 6, 4, 28.
31. $W = \frac{7T + 4H + 2K}{12}$, by 21, 19.
32. $X = \frac{7T + 4O + 2Q}{12}$, by 22, 17.
33. $Y = \frac{7T + 2H + 4K}{12}$, by 23, 20.
34. $\& = \frac{7T + 2O + 4Q}{12}$, by 25, 18.
35. $Z = \frac{7\frac{1}{2}T + O + 2Q}{12}$, by 24, 34.
36. $L = \frac{39T + 8H + 4K + 4O + 2Q}{36}$, by 11, 31, 32.
37. $M = \frac{39T + 4H + 2K + 8O + 4Q}{36}$, by 12, 31, 32.
38. $B = \frac{39\frac{1}{2}T + 4H + 8K + O + 2Q}{36}$, by 15, 33, 35.
39. $Q = \frac{20T + H + 2K + O + 2Q}{18}$, by 16, 33, 35.
40. $Q = \frac{20T + H + 2K + O}{16}$, by 39.
41. $N = \frac{94\frac{1}{2}T + 16G + 2H + 20I + K + 4O + 2Q}{54}$, by 13, 30, 37.
42. $O = \frac{45T + 4G + 2H + 5I + K + 4O + 2Q}{27}$, by 14, 30, 37.
43. $O = \frac{45T + 4G + 2H + 5I + K + 2Q}{23}$, by 42.
44. $G = \frac{213T + 40G + 8H + 32I + 4K + 4O + 2Q}{108}$, by 7, 29, 36.
45. $G = \frac{213T + 8H + 32I + 4K + 4O + 2Q}{68}$, by 44.
46. $H = \frac{48T + G + 4H + 4I + 2K + 2O + Q}{27}$, by 8, 29, 36.
47. $H = \frac{48T + 5G + 4I + 2K + 2O + Q}{23}$, by 46.
48. $I = \frac{658\frac{1}{2}T + 64G + 20H + 80I + 28K + 19O + 14Q}{324}$, by 9, 38, 41.

No.

49. $I = \frac{658\frac{1}{2}T + 64G + 20H + 28K + 19O + 14Q}{244}$, by 48.
50. $K = \frac{294T + 16G + 14H + 20I \times 25K + 7O + 8Q}{162}$, by 10, 38, 41.
51. $K = \frac{294T + 16G + 14H + 20I + 7O + 8Q}{137}$, by 50.
52. $G = \frac{1724T + 65H + 256I + 34K + 33O}{8 \times 68 = 544}$, by 45, 40.
53. $H = \frac{788T + 80G + H + 64I + 34K + 33O}{16 \times 23 = 368}$, by 47, 40.
54. $H = \frac{788T + 80G + 64I + 34K + 33O}{367}$, by 53.
55. $I = \frac{5408T + 512G + 167H + 238K + 159O}{244 \times 8 = 1952}$, by 49, 40.
56. $K = \frac{608T + 32G + 29H + 40I + 2K + 15O}{137 \times 2 = 274}$, by 51, 40
57. $K = \frac{608T + 32G + 29H + 40I + 15O}{272 = 8 \times 34}$, by 56.
58. $O = \frac{380T + 32G + 17H + 40I + 10K + O}{23 \times 8 = 184}$, by 43, 40.
59. $O = \frac{380T + 32G + 17H + 40I + 10K}{183}$, by 58.
60. $G = \frac{14400T + 32G + 549H + 2088I + 279O}{544 \times 8 = 4352}$, by 52, 57.
61. $G = \frac{14400T + 549H + 2088I + 279O}{4320 = 9 \times 480}$, by 60.
62. $G = \frac{1600T + 61H + 232I + 31O}{480}$, by 61.
63. $H = \frac{6912T + 672G + 29H + 552I + 279O}{367 \times 8 = 2936}$, by 54, 57.
64. $H = \frac{6912T + 672G + 552I + 279O}{2907 = 3 \times 969}$, by 63.
65. $H = \frac{2304T + 224G + 184I + 93O}{969}$, by 64.
66. $I = \frac{47520T + 4320G + 1539H + 280I + 1377O}{1952 \times 8 = 15616}$ by 55, 57.
67. $I = \frac{47520T + 4320G + 1539H = 1377O}{15336 = 27 \times 568}$, by 66.
68. $I = \frac{1760T + 160G + 57H + 51O}{568}$, by 67.
69. $O = \frac{54720T + 4512G + 2457H + 5640I + 75O}{183 \times 136 = 24888}$, by 59, 57.
70. $O = \frac{54720T + 4512G + 2457H + 5640I}{24813 = 3 \times 8271}$, by 69.
71. $O = \frac{18240T + 1504G + 819H + 1880I}{8271 = 3 \times 2757}$, by 70.
72. $G = \frac{13799040T + 46624G + 529920H + 1977152I}{480 \times 8271 = 3970080}$, by 62, 71
73. $G = \frac{13799040T + 529920H + 1977152I}{3923456 = 64 \times 61304}$, by 72.
74. $G = \frac{215610T + 8280H + 30893I}{61304}$, by 73.
75. $H = \frac{6917568T + 664192G + 25389H + 565568I}{969 \times 2757 = 2671533}$, by 65, 71.

No.

76. H $= \frac{6917568\,\text{T} + 664192\,\text{G} + 565568\,\text{I}}{2646144 = 64 \times 41346}$, by 75.

77. H $= \frac{108087\,\text{T} + 10378\,\text{G} + 8837\,\text{I}}{41346}$, by 76.

78. I $= \frac{15487200\text{T} + 1400064\text{G} + 513216\text{H} + 95880\text{I}}{568 \times 8271 = 4697928}$, by 68, 71

79. I $= \frac{15487200\,\text{T} + 1400064\,\text{G} + 513216\,\text{H}}{4602048 = 96 \times 47938}$, by 78.

80. I $= \frac{161325\,\text{T} + 14584\,\text{G} + 5346\,\text{H}}{47938}$, by 79.

81. G $= \frac{9809571420\text{T} + 85929840\text{G} + 1350472338\text{I}}{61304 \times 41346 = 2534675184}$, by 74, 77.

82. G $= \frac{9809571420\,\text{T} + 1350472338\,\text{I}}{2448745344 = 162 \times 919 \times 16448}$, by 81.

83. G $= \frac{65890\,\text{T} + 9071\,\text{I}}{16448}$, by 83.

84. I $= \frac{7247976552\text{T} + 658470852\text{G} + 47242602\text{I}}{47938 \times 41346 = 1982044548}$, by 80, 77.

85. I $= \frac{7247976552\,\text{T} + 658470852\,\text{G}}{1934801946 = 18 \times 919 \times 116963}$, by 84.

86. I $= \frac{438156\,\text{T} + 39806\,\text{G}}{116963}$, by 85.

87. I $= \frac{9829607228\,\text{T} + 361080226\,\text{I}}{116963 \times 16448 = 1923807424}$, by 86, 83.

88. I $= \frac{9829607228\,\text{T}}{1562727198 = 4594 \times 340167}$, by 87.

89. I $= \frac{2139662}{340167}$ T. by 88.

90. G $= \frac{2542309}{340167}$ T. by 83, 89.

91. C $= \frac{2578443\frac{1}{2}}{340167}$ T. by 3, 89, 90.

92. D $= \frac{2444094\frac{1}{2}}{340167}$ T. by 4, 89, 90.

93. B $= \frac{2918610\frac{1}{2}}{340167}$ T. by 27, 91.

94. A $= \frac{3088694}{340167}$ T. by 26, 91, 93.

95. E $= \frac{2930522}{340167}$ T. by 5, 92, 93.

96. F $= \frac{2772350}{340167}$ T. by 6, 92, 93.

97. H $= \frac{1984812\frac{1}{2}}{340167}$ T. by 77, 89, 90.

98. O $= \frac{1895418\frac{1}{2}}{340167}$ T. by 71, 89, 90, 97.

99. K $= \frac{1690314\frac{1}{2}}{340167}$ T. by 57, 89, 90, 97, 98.

100. V $= \frac{2056730}{340167}$ T. by 19, 97, 99.

101. U $= \frac{1958564}{340167}$ T. by 20, 97, 99.

102. W $= \frac{1141704}{340167}$ T. by 21, 100.

No.

103. Y $= \frac{1092671}{340167}$ T. by 23, 101.

104. Q $= \frac{879012\frac{1}{2}}{340167}$ T. by 40, 97, 98, 99.

105. R $= \frac{1726700}{340167}$ T. by 17, 98, 104.

106. S $= \frac{1387898}{340167}$ T. by 18, 98, 104.

107. X $= \frac{976739}{340167}$ T. by 22, 105.

108. & $= \frac{807338}{340167}$ T. by 25, 106.

109. Z $= \frac{517058}{340167}$ T. by 24, 108.

110. L $= \frac{1256832\frac{1}{2}}{340167}$ T. by 11, 102, 107.

111. M $= \frac{1201827\frac{1}{2}}{340167}$ T. by 12, 102, 107.

112. N $= \frac{2418926}{340167}$ T. by 13, 96, 111.

113. P $= \frac{1070883\frac{1}{2}}{340167}$ T. by 15, 103, 109.

"*Or thus, in Alphabetical Order.*

A $= 9\frac{27191}{340167}$ T.

B $= 8\frac{197274\frac{1}{2}}{340167}$ T.

C $= 7\frac{197274\frac{1}{2}}{340167}$ T.

D $= 7\frac{62925\frac{1}{2}}{340167}$ T.

E $= 8\frac{209186}{340167}$ T.

F $= 8\frac{51014}{340167}$ T.

G $= 7\frac{161540}{340167}$ T.

H $= 5\frac{283977\frac{1}{2}}{340167}$ T.

I $= 6\frac{98660}{340167}$ T.

K $= 4\frac{329646\frac{1}{2}}{340167}$ T.

L $= 3\frac{236331\frac{1}{2}}{340167}$ T.

M $= 3\frac{181326\frac{1}{2}}{340167}$ T.

N $= 7\frac{37757}{340167}$ T.

O $= 5\frac{194583\frac{1}{2}}{340167}$ T.

P $= 3\frac{503821}{340167}$ T.

Q $= 2\frac{198678\frac{1}{2}}{340167}$ T.

R $= 5\frac{25865}{340167}$ T.

S $= 4\frac{27230}{340167}$ T.

V $= 6\frac{15728}{340167}$ T.

U $= 5\frac{257729}{340167}$ T.

W $= 3\frac{121253}{340167}$ T.

X $= 2\frac{296405}{340167}$ T.

Y $= 3\frac{72170}{340167}$ T.

Z $= 1\frac{176891}{340167}$ T.

& $= 2\frac{127004}{340167}$ T.

"All this weight lying on the building, or wall, is not necessarily distinguished by a distinct calculation; because those evidently correspond with others which are situated in the ends of their respective rafters. For example, when the

rafter x R does not rest exactly upon its middle, the fulcrum, whether it sustains one-half the weight of the rafter at x, and the other on the wall, then also the half of the burden is placed at R.

"It is obvious, from this calculation, that the joinings about A, toward the middle of the framing, press most of all. Since the particular weight of these is about nine of the longer rafters (but of the others, less by a ninth part of the wood) to each of which there will be added, half the weight of the rafter for firmness deducted, lest by its own weight it should break, and moreover one-half of the weight of the joint C lying upon it, being about four of the rafters. And so, by computing the whole, the strength requisite, lest a rafter should give way, will equal more than thirteen times the weight of the rafters, and be about fourteen times $9\frac{27191}{340167} + 4\frac{394549}{1360668} = 13\frac{503313}{1360668} = 13\frac{167771}{453556}$: the computation in weight of each rafter.

"No doubt can now remain that the rafters, even the longest, can be made of such firmness as shall enable them to sustain any weight that may be placed upon them individually to fourteen times the weight of the whole; neither can it be doubted, that raftering of this description is the safest that can possibly be applied to purposes where great weights are to be carried.

"Another form of this construction. *Figure* 6 exhibits another form, differing from the preceding in this, that where the ends of two of the rafters lie upon a third, they are jointed by two distinct dovetails; into these a third rafter is notched, and all are so placed as to be supported by those parts: hence to the middle part of each rafter are fastened two others, but to opposite parts.

"*Figure* 7 exhibits the lateral face: the upper face is sufficiently obvious from *Figure* 6. All these rafters are of an equal length, and similar among themselves.

"But here, as in the preceding construction, the work may be more or less extended, and the condition of the timber will be equally determined both as to the aid it gives and the weight it will carry. For, as in the protracted area, the number of the beams is augmented, so is also the weight. But this construction is attended with a disadvantage from both the beams' weight lying upon one, which having to endure the burden on an individual part of the beam, it is more strenuously pressed; that is, it has to sustain the entire weight of two ends, one entire beam; for, in this construction, equal to that of the half, which in the preceding was not borne, is here to be supported at one and the same point; on this account, also, the wood at that mortise is very much weakened, by being cut away to enable it to support the two beams, which rest their tenons in one place. This in some measure seems to be compensated by the resting timbers being placed towards opposite parts, which in the preceding construction lay towards the same parts; although, in this also it is not of much consequence, especially if the ends of the beams, resting on the others, are not extended toward the centre, but kept pretty close to the outer part of the framing, which is easily done by the judicious management of the architect.

"But this inconvenience forms no substantial objection to the plan, since the rafters are sufficiently strong and well joined to support any proportionate weight, as will be obvious from the subjoined investigation of their strength.

"In looking at what is before us, the former of these figures seems the stronger, because the timbers are so disposed that the workmanship is more obvious to the eye; while in the latter it is scarcely distinguishable, and the intervals are so varied as to give the work a distorted appearance: yet in both they are squares; and in the latter the spaces beyond the half-rafter from the wall-beams are also resolved into the same figure.

"The calculation in this construction will result from the same principles as in the preceding; but here it will be much more expeditious, because, as all the timbers are of the same length, and they support the weight of the corresponding timbers about the centre, they are almost all pressed by an equality of weight about the same part: all which conduce to render the results more readily to be obtained.

"*Calculation adapted to this construction.*

"With respect to the facility of this calculation, it may be observed, that the points (whether five or four) which are similarly posited in respect of the scheme, and on that account support an equality of weight, are designated by the same symbol that was adopted in the preceding problem. But, here, on account of the individual pieces of wood supporting the same weight, and that too about the same part, the two ends of each rafter have to support the same weight; these ends we shall therefore express by the same symbols, the equal weight being denoted by a similar sign. Other methods of proof might be mentioned, but the foregoing will be sufficient for our purpose.

"SYNOPSIS OF THIS CALCULATION.

1. A $= \alpha = \frac{1}{2}$ T + B.
2. B $= \beta = \frac{1}{2}$ T + $\frac{1}{3}$ K + $\frac{1}{2}$ F.
3. C $= \frac{1}{2}$ T + A.
4. D $= \delta = \frac{1}{2}$ T + L.
5. E $= \varepsilon = \frac{1}{2}$ T + $\frac{1}{2}\beta$ + $\frac{1}{2}$ R.
6. F $= \frac{1}{2}$ T + $\frac{1}{2}$ C + $\frac{1}{2}$ G.
7. G $= \gamma = \frac{1}{2}$ T + E.
8. H $= \frac{1}{2}$ T + $\frac{1}{2}\alpha$ + $\frac{1}{2}$ D.
9. I $= \iota = \frac{1}{2}$ T + $\frac{1}{2}\varepsilon$ + $\frac{1}{2}$ N.
10. K $= \kappa = \frac{1}{2}$ T + $\frac{1}{2}$ H + $\frac{1}{2}$ I.
11. L $= \lambda = \frac{1}{2}$ T + $\frac{1}{2}\kappa$.
12. M $= \mu = \frac{1}{2}$ T + $\frac{1}{2}$ P.
13. N $= \nu = \frac{1}{2}$ T + $\frac{1}{2}\lambda$ + $\frac{1}{2}$ M.
14. P $= \pi = \frac{1}{2}$ T + $\frac{1}{2}\iota$.
15. Q $= \frac{1}{2}$ T + $\frac{1}{2}\gamma$.
16. R $= \rho = \frac{1}{2}$ T + $\frac{1}{2}\pi$ + $\frac{1}{2}$ Q.
17. C $=$ T + B, by 3, 1.
18. D $=$ T + $\frac{1}{2}\kappa$, by 4, 11.
19. F $= \frac{5}{4}$ T + $\frac{1}{2}$ B + $\frac{1}{2}$ E, by 6, 7, 17.
20. H $= \frac{5}{4}$ T + $\frac{1}{2}$ B + $\frac{1}{4}\kappa$, by 8, 1, 18.
21. M $= \frac{3}{4}$ T + $\frac{1}{4}\iota$, by 12, 14.
22. N $=$ T + $\frac{1}{4}\kappa$ + $\frac{1}{4}$ P, by 13, 11, 12.
23. N $= \frac{9}{8}$ T + $\frac{1}{4}\kappa$ + $\frac{1}{8}\iota$, by 22, 14.
24. Q $= \frac{3}{4}$ T + $\frac{1}{2}$ E, by 15, 7.
25. R $= \frac{9}{8}$ T + $\frac{1}{4}$ E + $\frac{1}{4}\iota$, by 16, 14, 24.
26. B $= \frac{9}{8}$ T + $\frac{1}{4}$ B + $\frac{1}{4}$ E + $\frac{1}{2}$ K, by 2, 19.
27. B $= \dfrac{9\text{ T} + 2\text{ E} + 4\text{ K}}{6}$, by 26.
28. E $= \frac{29}{16}$ T + $\frac{7}{24}$ E + $\frac{1}{8}$ I + $\frac{1}{3}$ K, by 5, 25, 27.
29. E $= \dfrac{87\text{ T} + 6\text{ I} + 16\text{ K}}{34}$, by 28.
30. H $= 2$ T + $\frac{1}{6}$ E + $\frac{1}{12}$ K, by 20, 27.
31. I $= \frac{17}{16}$ T + $\frac{1}{2}\varepsilon$ + $\frac{1}{16}$ I + $\frac{1}{8}\kappa$, by 9, 23.
32. I $= \dfrac{17\text{ T} + 8\varepsilon + 2\kappa}{15}$, by 31.
33. K $= \frac{31}{15}$ T + $\frac{7}{20}$ E + $\frac{43}{120}$ K, by 10, 30, 32.
34. K $= \dfrac{248\text{ T} + 42\text{ E}}{77}$, by 33.

35. I $= \frac{361\ \text{T} + 140\ \text{E}}{3 \times 77 = 231}$, by 32, 34.

36. E $= \frac{11389\ \text{T} + 952\ \text{E}}{34 \times 77 = 2618}$, by 29, 34, 35.

37. E $= \frac{1627\ \text{T} + 136\ \text{E}}{34 \times 11 = 374}$, by 36.

38. E $= \frac{1627}{238}$ T, by 37.

39. G $= \frac{1746}{238}$ T, by 7, 38.

40. Q $= \frac{992}{238}$ T, by 15, 39.

41. K $= \frac{1654}{238}$ T, by 34, 38.

42. L $= \frac{946}{238}$ T, by 11, 41.

43. D $= \frac{1065}{238}$ T, by 4, 42.

44. B $= \frac{2002}{238}$ T, by 27, 38, 41.

45. A $= \frac{2121}{238}$ T, by 1, 44.

46. C $= \frac{2240}{238}$ T, by 3, 45.

47. F $= \frac{2112}{238}$ T, by 6, 39, 46.

48. H $= \frac{1712}{238}$ T, by 8, 43, 45.

49. I $= \frac{1358}{238}$ T, by 32, 38, 41.

50. P $= \frac{798}{238}$ T, by 14, 49.

51. M $= \frac{518}{238}$ T, by 12, 50.

52. N $= \frac{851}{238}$ T, by 13, 42, 51.

53. R $= \frac{1014}{238}$ T, by 16, 40, 50.

That is, in Alphabetical Order.

A $= 8\frac{217}{238}$ T.	I $= 5\frac{168}{238}$ T.
B $= 8\frac{98}{238}$ T.	K $= 6\frac{226}{238}$ T.
C $= 9\frac{98}{238}$ T.	L $= 3\frac{232}{238}$ T.
D $= 4\frac{113}{238}$ T.	M $= 2\frac{42}{238}$ T.
E $= 6\frac{199}{238}$ T.	N $= 3\frac{137}{238}$ T.
F $= 8\frac{208}{238}$ T.	P $= 3\frac{84}{238}$ T.
G $= 7\frac{80}{238}$ T.	Q $= 4\frac{40}{238}$ T.
H $= 7\frac{46}{238}$ T.	R $= 4\frac{62}{238}$ T.

It appears from this calculation that the greatest of the separate weights will be A $= 8\frac{217}{238}$ T. When therefore upon this point (C C in the middle of the wood) there lie two A's (on both sides) it is $7\frac{196}{230}$ T; and so on, in like manner, lest any rafter give way by its own weight. Whence one-half the weight of the timber is determined. The strength requisite there, is the same, lest that beam give way, which is equal to the weight of the respective beams $8\frac{217}{238} + 8\frac{217}{231} + \frac{1}{2} = 18\frac{77}{238} = 18\frac{11}{34}$. But indeed this weight is not so great as to occasion any apprehension for the strength of the timber; for even if the timbers be pretty long, they are sufficient to bear any weight that may be laid upon them, to eighteen or even to nineteen times their own weight.

"Here the weight is indeed heavier than in the preceding case; for there, the pressure amounted only to fourteen times the weight of the timber.

"In the mean time, the conditions of this construction dispense with a multiplicity of rafters, as the length of the area within the walls extends to twelve times the length of the whole, the length and breadth of the rafters remaining. For in this case the rafters being joined are equal to 49, but in the other the longer are 40 and the shorter 20."

NAKED OF A COLUMN, OR PILASTER, the surface of the shaft or trunk, when the mouldings are supposed to project. Thus we say, a pilaster ought to exceed the naked of the wall by so many inches, and that the foliages of capital ought to answer to the naked of the columns.

NAKED OF A WALL, the remote face whence the projectures take their rise. It is generally a plane surface, and when the plan is circular, the naked is the surface of a cylinder, with its axis perpendicular to the horizon.

NAOS or NAVE (from the Greek *ναος*, *a temple*) the chamber or enclosed apartment of a temple. The part of the temple which stood before the naos, comprehended between the wall and the columns of the portico, was called the *pronaos*; while the corresponding part behind was called the *posticum*.

NAPIER'S BONES, or RODS, a contrivance of Napier to facilitate the performance of multiplication and division, explained by him, in his Rabdologia, published in 1617. The invention would perhaps have been more employed, but for his discovery of logarithms: but even yet it might be used with advantage by young arithmeticians in verification of their work.

These rods may be made of bone, ivory, horn, wood, pasteboard, or any other convenient material. There are five of them, and the face of each is divided into nine equal parts, each being subdivided by a diagonal line into two triangles. In these compartments or squares the numbers of the multiplication table are inserted, the units or right-hand figures being placed in the right hand triangle, and the tens in the left.

NARTHEX, the name of an enclosed space in the ancient Christian churches, and also of an ante-temple or vestibule without the church. To the Narthex the catechumens and penitents were admitted; and there appears to have been several such apartments in each church, but nothing certain is known of their position. Narthex is frequently used as synonymous with *porch* and *portico*.

NATTES, a name given to an ornament used in the decoration of surfaces in the architecture of the 12th century, from its resemblance to the interlaced widths of matting.

NATURAL BEDS, of a stone, the surfaces from which the laminæ were separated. It is of the utmost consequence to the duration of stone walls, that the laminæ should be placed perpendicular to the face of the work, and parallel to the horizon, as the connecting substance of these thin plates, or laminæ, is more friable than the laminæ themselves, and consequently liable to scale off in large flakes, and thus reduce the work to a state of rapid decay.

NAVE (from the Saxon *naf*) in architecture, the body of a church; or the place where the people are seated; reaching from the rail or baluster of the choir to the chief door. The ancient Greeks called the nave *pronaos;* the Latins frequently call it *cella*. *See* NAOS.

The nave of the church belongs to the parishioners, who are bound to keep it in repair, &c.

NAUMACHIA, the representation of a sea-fight among the Romans, which was sometimes performed in the Circus Maximus or amphitheatre, water being introduced sufficient to float ships; but more frequently in places made especially for the purpose, which were called Naumachiæ. Julius Cæsar appears to have been the first who gave a representation of a sea-fight on an extensive scale. He dug a lake in the Campus Martius for the purpose, which, however, was filled up in his life-time. Augustus also dug a lake near the Tiber for the same purpose, which was afterwards turned into a park or plantation. Another lake was dug in the Campus Martius by Caligula; but Claudius exhibited a naumachia on the lake Fucinus, now Celano. The old

naumachia, in which Titus is said by Suetonius to have exhibited a sea-fight, has occasioned some dispute among the learned; some understanding it to be the Circus Maximus, and others the lake dug by order of Augustus. Domitian appears to have been the first who erected a building of stone around these artificial lakes. Previous to his time the spectators appear to have sat upon wooden benches, which might be easily made to rise gradually above one another with the earth which had been dug out of the artificial lake. In later times the naumachia were usually surrounded with buildings like the amphitheatre or circus.

The ships which were engaged in these sea-fights were divided into two parties, which were called respectively by the names of different maritime nations, as the Tyrian and Egyptian fleets, the Sicilian and Rhodian. The combatants, who were called Naumachiarii, were usually composed of captives or criminals, who fought to death, unless saved by the clemency of the emperor. These sea-fights were said to have been exhibited on such a scale of magnificence and splendour as almost to surpass our belief. In the naumachia exhibited by Nero, there were sea-monsters swimming about in the artificial lake, and Claudius caused a Triton, made of silver, to be placed in the middle of the lake Fucinus, who was made, by machinery, to give the signal of attack with a trumpet. In Domitian's naumachia the number of ships engaged was almost equal to two real fleets, and in the sea-fight on the lake Fucinus, there are said to have been no fewer than 19,000 combatants.

NEBULE (from the Latin *nebula*, a cloud) an ornament of the zig-zag form, but without angles. It is chiefly found in the remains of Saxon architecture, in the archivolts of doors and windows.

NECK, of a capital, the space between the channelures and the annulets of the Grecian Doric capital. In the Roman Doric, it is the space between the astragal and the annulet.

The rich Ionic capitals of Minerva Polias, and Erechtheus, at Athens, have neckings, but most other antique examples of the Ionic order are without them.

NEEFS, PETER, in biography, a painter of architecture, and a disciple of Henry Steenwick, born at Antwerp, in the year 1570. He was particularly skilful in perspective, and generally chose such subjects as required a considerable display of that science; such as the interior of churches, splendid halls, &c. These he drew with great neatness and effect, and painted very clear, gay, and agreeable, but he never equalled the truth of his master. His execution of the mouldings and masses of columns, in the various Gothic works which he chose as models, is too neat, and too much made up of lines, for real imitation; but that very defect gives them lightness; and the truth with which he drew the forms of the building, and proportioned his figures, which are very freely wrought, though not unfrequently by other artists, renders them very agreeable. Van Fulden, Teniers, and Breughel, were often called upon to assist Neefs, and by their skilful execution made amends for his want of knowledge of the human figure. He died at the age of 81, leaving a son, whose name also was Peter, and who is denominated *the Young*, in contradistinction to his father, whose excellence in the art of painting he never rivalled, although he had the advantage of his example and instruction, and practised in the same branch of the art.

NEGATIVE QUANTITIES, are those quantities which are preceded or effected with the negative sign.

Negative sign, in algebra, is that character or symbol, which denotes subtraction, being a short line preceding the quantity to be subtracted, and is read *minus;* thus, $a - b$ denotes that the quantity b is to be taken from the quantity a, and is read *a minus b;* like signs produce *plus*, and unlike signs *minus*, hence $- a \times b = + a b$. The introduction of this character has given rise to various controversies, with regard to the legality or illegality of certain conclusions depending upon it; some maintaining, that as a negative quantity is in itself totally imaginary, it ought not to be introduced into a science, the excellency of which depends upon the rigour and certainty of its conclusions; while others, running into the opposite extreme, have endeavoured to illustrate what will not admit of illustration, and thus, like other zealots, have been the greatest enemies of the cause they were endeavouring to defend.

It is in vain to attempt to define what can have no possible existence; a quantity less than nothing is totally incomprehensible; and to illustrate it, by reference to a debtor and creditor account, to say the least of it, says Barrow, is highly derogatory to this most extensive and comprehensive science.

NERVES, in architecture, the mouldings of the groined ribs of Gothic vaults.

NET, or RETE, (from the Saxon, *net*, derived from the Gothic, *nati*) the covering of a body or geometrical solid. *See* ENVELOPE and SOFFIT.

NET MEASURE, in building, is when no allowance is made for finishing; and in artificers' works, when no allowance is made for waste of materials.

NET MASONRY. *See* MASONRY and STONE WALLS.

NEWEL, in architecture, the upright post or central column, round which the steps of a circular staircase are made to wind; being that part of the staircase by which they are sustained.

The newel is, properly, a cylinder of stone, which bears on the ground, and is formed by the ends of the steps of the winding-stairs.

There are also newels of wood, which are pieces of timber placed perpendicularly, receiving the tenons of the steps of wooden stairs into their mortises, and wherein are fitted the shafts and rests of the staircase, and the flights of each story. In some of the Tudor and Elizabethan residences, some very fine examples may be seen of the newel richly ornamented, and adding much to the beauty of the staircase.

NICHE, (from the Italian, *niechia*, shell) in architecture, a cavity, or hollow place, in the thickness of a wall, to place a figure or statue in.

Niches are made to partake of all the segments under a semicircle. They are sometimes at an equal distance from the front, and parallel or square on the back with the front line; in which case they are called *square recesses*, or *square niches*. The larger niches serve for groups of figures, the smaller for single statues, and sometimes only for busts.

Great care must be taken to proportion the niches to the figures, and the pedestal of the figures to the niches.

Niches are sometimes made with rustic work.

Few niches are to be found in Grecian antiquity, but what may be supposed to have been erected under the dominion of the Romans.

In the Pantheon at Rome, the niches are all rectangular recesses, dressed in the same manner as the apertures of doors; the columns are insulated, and the entablatures crowned with triangular and circular pediments alternately. The large niches, or exedræ, on the sides, have cylindrical backs, but finish at top with the soffit of the architrave of the general entablature; these niches have each two columns placed in the aperture which supports the architrave. The entablature is continued without any break or interruption of recesses, except by the large cylindro-spherical niche

opposite the entrance, and the side through which the entrance is made; but neither of these is supposed to have been in the original edifice, but to have been introduced at some later period. The large niches on the exterior side within the portico are cylindro-spherical, without any dressings. In the remains of the piazza of Nerva (see Desgodetz's *Antiquities of Rome*) a niche is exhibited upon a circular plan, with a rectangular front and cylindrical head in the middle of the attic, over the intercolumns; the axis of the cylinder, forming the head of the niche, is horizontal, and parallel to the naked of the wall. This niche is surrounded with an architrave, standing upon the base of the attic, which projects to receive it, and the head of the architrave supports the crowning of the attic.

The *Ruins of Palmyra*, by Wood, exhibit niches of various kinds, some of which are very fantastically dressed. The inside of the portico of the temple of the sun has two niches, one on each side of the doorway, with cylindrical backs, terminated at the head with spheroidal tops, which show an ellipsis on the face with its greater axis horizontal. These niches are decorated with four attached columns, whose axes are placed in the surface of a cylinder: the entablature over the columns terminates under the spheroidal head; the head is decorated with a shell, and surrounded on the front with an elliptic archivolt upon the face of the wall. *See Plates* VI. and IX. *of the Ruins of Palmyra.*

The inside of the portico of the court of the same edifice, shown in *Plate* XI. exhibits two niches on each side of the doorway, which terminate on the front in parallel lines, and with a semicircle at the head; they finish with a pilaster on each side: the capital, which is Corinthian, serving as an impost to the archivolt surrounding the head. Besides this dressing, a column is placed on each side, attached to the wall, so that the distance between the insides of the columns is greater than that between the outsides of the pilasters; the architrave of the entablature rests upon the archivolt of the head of the niche.

The inside of the court of the great temple of Balbec exhibits niches dressed in the most whimsical manner: the sides of the niches terminate with the wall in vertical lines, and the head with the said wall in a semicircle.

The sides finish with Corinthian pilasters; the entablature is horizontal over the pilasters; but the architrave and cornice are carried round the semicircular head of the niche, which appears to be spherical within, being decorated with a shell resting upon an impost, and corresponding in its situation to the height of the capital on each side. The inside of the temple of Jupiter, at Spalatra, is decorated with niches, one between every two columns; the one opposite the entrance, and those on each of the two sides, are rectangular below, but finish with cylindric heads: the axis of the cylinder, which forms the head, is parallel to the horizon, and in the direction of radii which belong to the cylindric wall, in which these niches are placed.

The other four niches are cylindro-spherical; that is, they have cylindrical backs, and are terminated with spherical heads. All these niches are decorated with an impost, continued from side to side, and the heads are furnished with archivolts.

In the pointed style of architecture, niches are sometimes highly decorated. The back very frequently consists of three sides of a hexagon, and the head is terminated with a rich canopy, forming a complete hexagon with the interior; the under part of each of the three projecting sides of the canopy has a Gothic arch, and the soffit represents a groined vault, decorated with tracery and ribs in the most beautiful manner.

The bottoms of these niches are formed by a table of the same shape as the head, and terminate below in the form of a pendant.

The ceiling of the canopy represents the groined roof of an hexagonal building in miniature, as some of the highly decorated chapter-houses exhibit; the top of the canopy finishes with battlements; and the vertical angles are sometimes finished with pendant buttresses, which are surmounted with pinnacles elaborately finished with crockets.

Niche, in carpentry, the wood-work to be lathed over for plastering.

The most usual construction of niches in carpentry, are those with cylindrical backs and spherical heads, called *cylindro-spheric niches;* the execution of which depends upon the principles of spheric sections.

As all the sections of a sphere are circles, and those passing through its centre are equal, and the greatest which can be formed by cutting the sphere; it is evident, that if the head of a niche is intended to form a spherical surface, the ribs may be all formed by one mould, whose curvature must be equal to that of a great circle of the sphere, viz., one passing through its centre: but the same spherical surface may be formed by ribs of wood moulded from the sections of lesser circles, in a variety of ways; though not so eligible for the purpose as those formed of great circles; because their disposition for sustaining the lath is not so good, and the trouble of moulding them to different circles, and of forming the edges according to different bevels, in order to range them in the spherical surface, is very great, compared with those made from great circles.

The regular dispositions for the head of a niche are the following:

The ribs of niches are generally disposed in a vertical plane, parallel to each other, or intersecting each other in a vertical line. When the line of intersection passes through the centre of the sphere, all the ribs are great circles; but if the line of intersection do not pass through the centre of the sphere, the circles which form the spherical surface are all of different radii.

When the ribs are fixed in parallel vertical planes, their disposition is either parallel to the face of the wall, or parallel to a vertical plane passing through the centre of the sphere perpendicular to the surface of the wall; and this will be understood whether the surface be a plane, or that of a cylinder, or that of a cylindroid.

Though these dispositions are the most common and most fit for the purpose, there is still another regular position of the ribs of a niche, which is easily constructed in practice, viz. by making all the ribs intersect in a line passing through the centre of the sphere perpendicular to the surface of the wall; but this method is not so eligible for lathing upon.

Another method is by making the planes of the ribs parallel to the horizon: this is not only attended with great labour in workmanship, but is incommodious for lathing upon.

The number of positions in which the ribs of a niche may be placed are almost infinite; as the ribs may have a common intersection in a line or axis obliquely situated to the horizon, or their position may be in parallel planes obliquely situated to the horizon: but the regular positions, already enumerated, ought to be those to which the carpenter should direct his attention.

Plate I. *Figure* 1, No. 2, the elevation of a niche, where all the ribs intersect each other in a vertical line, coinciding with the inside of the front rib, as shown by the plan, No. 1.

To describe any one of the ribs, as *m n*, continue the inside circle of the plan round beyond the wall, as far as may be

found necessary: produce *f i*, the base of the rib, to meet the opposite circumference in *g*; bisect *g e* at *h*; from *h*, with the radius *h e*, describe the arc *e l*; draw *d f* perpendicular to the other side of the plan of the rib, cutting *g e* at *f*; from *h*, with the radius *h f*, describe the arc *f k*; from the centre draw *i n* perpendicular to *g e*, the base, cutting the other circles at *k* and *l*; from the same centre, *h*, draw *m n* at any convenient distance, so as to make the rib sufficiently strong: the two inner arcs *f k*, and *e l*, show the part to be taken from the side of the rib in order to range its inner edge. In the same manner every other rib may be described.

Figure 2, No. 2, the elevation of a niche, where the ribs are posited in parallel vertical places perpendicular to the face of the wall.

The method of describing the ribs is as follows: Draw a line through the centre of the circle which forms the plane, parallel to the face of the wall. Suppose it were required to describe the rib whose base is *f h*: produce *f h* to meet the line parallel to the face of the wall in *g*; from *g*, as a centre, with the distance *g f*, describe the arc *f k*; draw the short line *d e* perpendicular to *g f*, cutting *d f* in *e*: from *g*, with the radius *g e*, describe the arc *e i*, so that *e i* and *f k* may terminate upon the inside of the front rib, A C, in the points *i* and *k*: then *e i* and *f k* will show the bevelling of the edge in order to range in the spherical surface.

In the same manner may all the other ribs be described.

Figure 3, shows the method of forming the spherical head of a niche, when the planes of the ribs are parallel to the front rib, or to the face of the wall. No. 1, the plan; No. 2, the elevation. The figure is so obvious as hardly to require any description, the ribs being all semicircles of different diameters, as shown by the plan: the parts darkly shadowed, are the places where the ribs come in contact with the plate or sill on which they stand; and show the degree of bevelling requisite for the edges, in order that they may range with the spherical surface. This disposition of the ribs is very convenient for fixing the laths, which may be all directed towards the centre, the workmanship in bevelling is very considerable.

In order to strengthen the work, a vertical rib is made to pass through the centre of the sphere, perpendicular to the surface of the wall.

Figure 4, is a very convenient method of forming the head of a niche, by making the planes of all the ribs to intersect in a common axis, passing through the centre of the sphere, perpendicular to the surface of the wall; but it is not so convenient for fixing the laths.

Plate II. *Figure* 1, is the most convenient method of any for fixing the laths, and the ribs are all described from one mould: they need only be cut to different lengths in order to agree with their seats or plans.

No. 1, is the elevation; No. 2, the plan. The lengths of the ribs are shown below, at No. 3, 4, and 5. The bases of the different ribs are taken from their seats on the plan. The double lines show the bevel at the top, where they come in contact with the back of the front rib.

Figure 2, is a different construction from the foregoing methods, which all spring from a horizontal plane passing through the centre of the sphere, and consequently the cylindrical surface will be a tangent to the spherical surface, at their junction. Whereas, in the present instance, the head of the niche is still spherical, but the horizontal plane from which it springs is higher than the centre of the sphere: this occasions a little more difficulty in the formation of the ribs, of which the construction is as follows:

The plan, or springing rib, which forms the top of the cylindric back, and the front rib, which is the segment of a circle, being given; to form the moulds of the back ribs.

Through the centre, *d*, of the plan, draw L M parallel to G I, the seat of the front rib; from *d*, with the radius *d* G, or *d* I, describe the arcs G L and I M; draw *d e* perpendicular to L M; then find the centre, E of the front rib; and draw D E perpendicular to A C, cutting A C in D; make *d e* on the plan equal to D E; from *e*, as a centre, with the radius *e* L, or *e* M, describe the arc L *m n o* M, which will be the curve of all the ribs.

To find the length required for any rib.

Let *f*, *h*, and *k*, be the points where the back ribs join the back of the front rib: from *d*, as a centre, with the distance *d f*, describe the arc *f g*, cutting L M at *g*; draw *g m* perpendicular to L M: then the part *m* M is the length which will stand over the seat of the rib, which meets at *f*. In the same manner, the lengths of the other ribs, which meet at *h* and *k*, will be ascertained; and thus having obtained the ribs for one half, the other half is also found; they being duplicates of each other.

The method of bevelling the heads of these ribs is the same as in the preceding examples.

The plan of a niche in a circular wall being given, to find the front rib.

Plate III. *Figure* 1, *No.* 1, is the plan given, which is a semicircle, whose diameter is *a b*; and *a*, *i*, *k*, *l*, *m*, *h*, the front of the circular wall; suppose the semicircle to be turned round its diameter, *a b*, so the point *v* may stand perpendicular over *h* in the front of the wall, the seat of the semicircle standing in this position upon the plan will be an ellipsis; therefore divide half the interior arc of the plan into any number of equal parts, as five; draw the perpendiculars 1 *d*, 2 *e*, 3 *f*, 4 *g*, 5 *h*; upon the centre, *c*, with the radius *c h*, describe the quadrant of a smaller circle, which divide into the same number of equal parts as the interior of the plan; through the points 1, 2, 3, 4, 5, draw parallel lines to *a b*, to intersect the others at the points *d*, *e*, *f*, *g*, *h*; through these points draw a curve, and it will be an ellipsis; then take the stretch-out of the interior of the plan, round 1, 2, 3, 4, 5, and lay the divisions from the centre both ways at F, stretched out; take the same distances *d i*, *e k*, *f l*, *g m*, from the plan, and at F make *d i*, *e k*, *f l*, equal to them, which will give a mould to bend under the front rib, so that the edge of the front rib will be perpendicular to *a*, *i*, *k*, *l*, *m*.

Note, The curve of the front rib is a semicircle, the same as the ground-plan; and the back ribs at C, D, and E, are likewise of the same curve.

The reason of this is easily conceived, the niche being part of a sphere, the curvature must be everywhere the same, and consequently the ribs must fit upon that curvature.

Note, The curve of the mould F will not be exactly true, as the distances *d i*, *e k*, *f l*, &c. are rather too short for the same corresponding distance upon the soffit F; but in practice it will be sufficiently near for plaster-work.

In applying the mould F, when bent round the under edge of the front rib, the straight side of the mould, F, must be kept close to the back edge of the front rib; and the rib, being drawn by the other edge of the mould, will give its place over the plan.

C, D, E, are the back ribs shown separately.

The plan and elevation of an elliptic niche being given, to find the curve of the ribs.

PLATE IV. *Figure* 1.—Describe every rib with a trammel, by taking the extent of each base, from the plan whereon the ribs stand, to its centre, and the height of each rib to the

height of the top of the niche; it will give the true sweep of each rib.

To range the ribs of the niche.—There will be no occasion for making any moulds for these ribs, but make the ribs themselves; then there will be two ribs of each kind: take the small distances 1 *c*, 2 *d*, from the plan at B, and put it to the bottom of the ribs D and E, from *d* to 2, and *e* to 1; then the ranging may be drawn off by the other corresponding rib, or with the trammel; as for example, at the rib E, by moving the centre of the trammel towards *e*, upon the line *e c*, from the centre, *c*, equal to the distance 1 *e*, the trammel-rod remaining the same as when the inside of the curve was struck.

Given one of the common ribs of the bracketing of a cove, to find the angle-bracket for a rectangular room.

Figure 2.—Let H be the common bracket, *b c* its base; draw *b a* perpendicular to *b c*, and equal to it draw the hypothenuse *a c*, which will be the place of the mitre; take any number of ordinates in H, perpendicular to *b c*, its base, and continue them to meet the mitre line, *a c*, that is, the base of the bracket, at I; draw the ordinates of I at right angles to its base; then the bracket at I, being pricked from H, as may be seen by the figures, will be the form of the angle-rib required.

Note,—The angle-rib must be ranged either externally or internally, according to the angle of the room.

NICHE, *Angular*, one formed in the corner of a building.

NICHE, *Cul de Four of a.* *See* CUL DE FOUR.

NICHE, *Ground*, that which instead of bearing on a massive base, or dado, has its rise from the ground; as the niches of the portico of the Pantheon at Rome. Their ordinary proportion is two diameters in height, and one in width.

NICHE, *Round*, one whose plan and circumference are circular.

NICHE, *Square*, a niche whose plan and circumference are square.

NICHED COLUMN. *See* COLUMN.

NICOMEDES, an ancient geometrician, celebrated for having been the inventor of the curve named the *conchoid*, which has been made to serve equally for the resolution of the two problems relating to the duplication of the cube, and the trisection of an angle. It was much used by the ancients, in the construction of solid problems. Sir Isaac Newton approved of it for trisecting angles, or finding two mean proportionals, and for constructing some other solid problems, as may be seen in his *Arithmetica Universalis*. It is not certain at what period Nicomedes flourished, but it was probably at no great distance from the time of Eratosthenes, who holds him up to ridicule on account of the mechanism of his *Mesolabe*, and also from the circumstance that Geminus, who lived in the second century before the Christian æra, wrote on conchoids, of which Nicomedes was then allowed to be the inventor.

NIDGED ASHLAR, a kind of ashlar used in Aberdeen, which is brought to the square by means of a cavil, or hammer, with a sharp point; whereby the asperities of the stone may be reduced in any degree proportioned to the time employed. As the species of stone found in that country is so very hard as to resist the mallet and chisel, this sort of operation becomes necessary.

NOGS, the same as WOOD-BRICKS, which see. The term is used in Liverpool, and perhaps in other parts of Lancashire.

NOGGING, a species of brickwork carried up in panels between quarters.

NOGGING-PIECES, horizontal boards placed in bricknogging, nailed to the quarters, in order to strengthen the brickwork. They are disposed at equal altitudes in the brickwork.

NONAGON, (Greek,) a figure of nine sides, and consequently of as many angles.

NORMAL LINE, in geometry, a term used for a perpendicular line. *See* PERPENDICULAR and SUBNORMAL.

NORMAN ARCHITECTURE, a style of architecture closely allied to the debased Roman examples of the Eastern and Western empires, and with them may be conveniently included under the general title of Romanesque. It can scarcely, however, be ranked as a division of equal importance with either the Byzantine or Lombardic, of both of which it is a modification, approximating more closely to the latter, but maintaining a general resemblance with both. It may perhaps be correctly considered as a sub-division of the same style, viz., the Romanesque.

The Norman style flourished primarily and principally in Normandy, as its name implies, but became prevalent in many other places, wherever the Normans obtained influence or dominion; amongst others, in this country. When the style was first introduced into England, it is a matter of considerable difficulty to determine, some persons affirming that it was introduced by the Conqueror, others by Edward the Confessor, while a third party maintain that it was but a development of the Saxon, or style of building immediately preceding that under consideration, by whatever title it may be designated. Some writers entirely ignore the Saxon as a distinct style, including all the examples usually classified under that name, under the same designation as the latter, or Norman style, supposing the earlier examples to be but uncouth and unskilful imitations of the continental architecture. In favour of this assertion, it is argued, that it is very improbable that a method of building, practised on the continent, should have remained unknown in England for any length of time, notwithstanding the frequent intercourse of neighbouring nations, whereas we have good evidence that the Norman style was fully developed abroad at least a century before its general adoption in this island. The second statement, as to the introduction of the style by Edward, is founded, we believe on the authority of Matthew Paris, who says, that Edward rebuilt Westminster Abbey in a new style, from which others took the idea. This passage has led antiquaries to conclude, that the style referred to was the Norman, and that it was entirely unknown in England before that time; this, however, amounts to little better than conjecture.

For our own part, we are inclined to consider the Saxon and Norman as, to a certain extent, distinct styles, although emanating from the same grand type, and, for that reason, in some sense modifications of each other. They are both derived from the Roman, and are both developments of the Romanesque or debased Roman, but here we imagine they part company, and take each its own course; they bear such a similarity to each other, as might be expected from descendants of a common stock, but of different branches of the same family. The Saxon style was reared on an uncultivated soil, and tended by rude hands, while the Norman was developed under more favourable circumstances. When the Romans invaded Britain, they naturally introduced the style of building then prevalent in their own country, as far, at least, as circumstances would permit. The want, however, of proper materials or tools, as well as the insufficiency of skilful workmen, must have put a limit to their success in this imitation, as we find to have been the case with their erections in this island, which were very rude in comparison with those of Rome. When the Romans were recalled, and the Britons left defenseless and unprotected against their formidable foes in the north, we may suppose that the art of building was

out little practised; and whatever edifices were erected during that period, must have been of a still ruder character than those of a preceding age. The Saxons do not seem to have had any mode of building of their own, but followed the method which they found practised in the country; their buildings were for the most part composed of timber, but sometimes of stone, and Bede speaks of the monastery at Wearmouth being erected after the Roman manner, and states that workmen were procured from France for the purpose. The Roman manner is contrasted with the Scotch, which latter term was applied apparently to the wooden structures. From the fact of foreign workmen being employed, it would appear reasonable to suppose that some foreign peculiarities might have been introduced by them. The mere fact, however, of French workmen being sent for into England, would prove that they were considerably further advanced in the art than those who sent for them; and it is probable that such importations of foreign artisans led to the introduction of some peculiarities of continental architecture, which however was not introduced in an entire and complete form until after the Conquest.

Many writers apply the term Lombardic to this style; but although, as we before observed, there is a near resemblance in many points, yet, on the other hand, there are not a few distinctions between the Norman and Italian Lombardic, *e. g.*, the former is wanting in a feature which is very conspicuous in Lombardic churches, the dome or cupola, nor has it the low pedimental roof extending over the whole façade. The sloping arcade in the gable is absent, as are likewise the tiers of external galleries or arcades in the façades and sides of buildings. Circular windows are not so common or prominent as in Italian buildings, nor do we meet with the peculiar projecting porch, with its columns resting on the backs of animals. Some of the details of the style, such as mouldings, windows, &c., are similar to those of the Byzantine. It agrees also with the Saxon in its massive proportions, the shape of its arches and piers, and in general construction; in some matters of detail also, such as the zig-zag ornament; it differs from it, however, amongst other matters, in finish and general decoration, the Norman bearing a much greater share of enrichment than its predecessor, and being, in fact, a much more highly-cultivated style of building.

Having given this general and rapid sketch of the origin and nature of Norman architecture, as well as of the relation it bears to other cognate modes of building, we shall proceed to consider the subject somewhat more in detail, referring more especially to the character and peculiarities of the style. We must premise, that it is our intention to confine ourselves almost exclusively to the consideration of the style as it is developed in this country; the difference, however, between the English and Continental mode of treatment, is not very considerable.

The style may be said to have been fully developed in this country soon after the successful invasion, by Duke William of Normandy; whether it had arrived at any degree of perfection before that time, it is difficult to say; but it may be said to have flourished from the middle of the eleventh century, and prevailed to the latter part of the twelfth, or the close of the reign of Henry II. It is styled generally, the architecture of the twelfth century, and dates from 1066 to 1170, or, if the Transition or Semi-Norman be included, to 1200. The conqueror and his countrymen were great builders, and the monkish chronicles tell us, that after their arrival, churches were erected in almost every village, and monasteries were seen to arise in the towns and cities, designed in a new style of architecture. From Doomsday book, we learn that the number of churches had increased to such an extent, that at the time of its compilation, there were no less than seventeen hundred in existence.

The *plans* of the larger churches belonging to this style, such as those of cathedrals, and other ecclesiastical establishments, are usually cruciform; having a low massive tower at the intersection between the nave, choir, and transepts; the choir being frequently terminated with a semicircular apse. The aisles of the nave are frequently continued at the sides of the choir and round the apse, and in this case the high altar is situated between the easternmost piers, with a screen or reredos at its back, stretching between the piers. Thus a space was left clear behind the altar, which was named the retro-altar, and this allowed of processions passing entirely round the church. In some instances, the choir is surrounded with chapels, having likewise apsidal terminations. The aisles were extremely narrow, sometimes not more than from four to six feet in width. The western façades are occasionally flanked by towers, but more frequently by only turrets or buttresses.

The parish churches are generally of small dimensions, and consist of a nave usually without either porch or aisles, chancel and tower, the latter being sometimes at the west end, and at others between the nave and choir, as in cruciform churches. This last disposition is somewhat curious, but in some instances of the kind, arches of construction have been discovered in the north and south walls of the tower, a fact which gives every reason to suppose, that transepts formed a part of the original design, and were intended to be added at some subsequent period. The chancel in these smaller churches also, sometimes terminated in a semicircular apse. Not unfrequently, small churches consisted of nave and chancel only, without any tower or other appendage.

The *walls* of buildings of this period, were of immense thickness, but the masonry was not solid, being composed of two external walls, or facings of ashlar-work, having the intermediate space filled in with grouted rubble, gravel, flints, &c. Sometimes, however, the walls are made up of solid rubble-work, with quoins of ashlar. The joints of ashlaring in early work are extremely wide, being frequently as much as an inch in thickness. Many walls of the first description have failed, from the outward pressure of the core of loose material, and it is not an unfrequent occurrence to see a Norman wall considerably out of the perpendicular. The introduction of buttresses at a later period, led to a great improvement in the construction of walls, adding materially to their efficiency and strength; while at the same time it lessened the consumption of material.

Arches are almost invariably of the semicircular form, but occasionally stilted, and the only variety in the proportions of arcades, depends upon the height of the piers, the height of the opening averaging in general about twice its width. The earliest arches are simply semicircular apertures in the wall, with a plain or single soffit; but owing to the extreme thickness of the walls, the intrados was very soon broken into two surfaces, so as to form a concentric rib or sub-arch attached to the soffit of the outer or main arch; in the majority of instances, the sub-arch is placed in the centre of the main arch, so as to form a recess or angle on either side, but occasionally, the sub-arch is set back, so as to present a recess on one side only, the other side being flush with the face of the wall. Sometimes we find two sub-arches, one under the other, thus presenting three soffits, and two recessions on either side of the arch. The edges of these soffits are for the most part rectangular, but are sometimes chamfered or rounded, which is an indication of later work; still later in the style, we find round and other mouldings

introduced, and the intradosses and faces of the arches enriched with the zig-zag and other mouldings and ornaments, characteristic of the style. Some chancel-arches are deeply recessed, and enriched with a number of decorative mouldings, as are also the arches of doorways, of which we shall speak more particularly presently.

The *piers* supporting the principal arches of construction, such as those separating the nave and aisles, are exceedingly massive, and frequently of stunted proportions. The simplest form presents a plain *shaft* on a square plan, which was afterwards recessed at the four angles with a rectangular nook, and this again was frequently filled up with a slender shaft. The same form is not unfrequently varied in appearance by the addition of a semicircular projection on two sides of the pier, so that we have a square pier recessed at the angles, into which recesses slender circular shafts are introduced, and having half a cylindrical column of massive proportions engaged to two opposite sides of the pier, the remaining sides being left plain: the former answer the purpose of supports to the sub-arches, while the latter range with the length of the building. This plain face was sometimes broken by a lofty shaft reaching from the ground to the springing of the vault, commonly termed a vaulting-shaft. Massive cylindrical shafts are very common, and are sometimes enriched with spiral or longitudinal flutings or bands, and sometimes with the zig-zag ornament disposed in a variety of ways. Octagonal shafts are also to be met with, though not nearly so frequently as the preceding, with which they sometimes alternate in a series of arches: sometimes, too, the shafts are made to appear as made up of a cluster of slender pillars. Cylindrical shafts, such as form principal supports in an edifice, are most frequently, as we have just observed, of massive proportions, but in one or two instances we find them approximating to classical proportions, as in Becket's Crown, Canterbury, in which example they bear in every respect a closer resemblance to the classical than probably in any other in England. Slender circular shafts, however, are very much employed as subordinate members and ornamental accessories, an example of which has been alluded to in the case of the square pier with nook-shafts at the angles; they are also much employed in the jambs of doorways and windows in a similar position, and as bearing shafts where an arch is subdivided into two or three apertures, as in two-light windows, and in the triforia and clere-stories of large churches. They are used very largely in the blank arcades which decorate the walls, and also as vaulting-shafts. In all such cases their proportions and treatment differ very considerably: some are much more slender than others, and some are plain, whilst others are enriched with carving of various patterns, amongst which the spiral groove or band of the zig-zag ornament are of constant occurrence: sometimes, too, spiral bands intersect each other so as to form diamond-shaped compartments throughout the surface; and at other times the shaft is ornamented with scroll-work, or diamond-shaped leaves, and such like enrichment. In principal piers we occasionally but rarely find clustered shafts.

The *capitals* partake of great variety of character, some assimilating more or less closely to the Corinthian and other classical examples. They are for the most part, however, rude and unskilful imitations, and have a heavy appearance when contrasted with the originals; the foliage is more crowded and irregular, and the capital itself much more squat, and therefore less elegant, than the classical examples. Many specimens of sculptured foliage exist which can scarcely be said to have been borrowed from such sources, some of which are not unworthy of praise. Some have interlaced bands or foliage in slight relief from the surface, and others are sculptured with grotesque representations of men and animals. Many capitals are quite plain, the most common of which is the cushion capital: this is of cubical form, being rounded at the lower end to meet the shaft, the profile of the curve presenting somewhat the appearance of the ovolo moulding; or it may be described as an inverted cone of convex contour spreading upwards, but intersected at about half its height by four vertical planes parallel to the four sides of the abacus, which produce as many flat surfaces rectilinear at the top and sides, but convex at the lower side where it intersects with the curve. Sometimes the side of the capital consists of many such figures of smaller dimensions placed side by side, the lower edge of the flat surface presenting a scalloped appearance, and beneath each of the scallops is a kind of inverted semi-cone, which meets the neck-mould of the shaft. The variety of capitals is, however, so great, that it would be useless to attempt to describe them all; they almost invariably terminate with a heavy square abacus, with a plain face chamfered only on the lower edge.

The *base* mouldings are set upon a shallow rectangular plinth, and consist either simply of a quirked ovolo reversed, or otherwise of some imitation or modification of the classic bases; the angles of the plinth are often ornamented with leaves or other ornaments, falling over from the base mouldings.

Piers and pillars are very greatly varied even in the same building, and in the same part of it; and this, too, not only in the minutiæ of decoration, but also in the entire form of the shaft and capitals, so that two very dissimilar designs are frequently seen in close proximity, forming supports to the same arcade.

Mural or blank arcades are a very common feature in this, as also in the Lombardic style; they sometimes cover the greater portion of both external and internal walls, but are more common on the exterior, especially on the façades, the clere-stories, and the upper stories of towers. The arches are mostly semicircular, resting upon slender pillars with capitals and bases, which, together with the shafts, bear various degrees of enrichment; sometimes, however, the arches intersect each other, producing at their intersection arches of the pointed form; pointed arches are employed alone, but only in late examples. The arcades are for the most part of small dimensions, but they vary in size, as also in proportions, some of them being exceedingly high in comparison to their width. In the interiors of larger churches, the space or width occupied by each arch in the lower story, is frequently divided into two arches, enclosed within a larger one in the triforia, and into three arches in the clere-story, the central one being loftier than the others, and the whole contained within a larger one.

Doorways in this style are to be found in great variety, from the most simple to the most elaborate. The simplest form consists of merely a plain semicircular-headed aperture, with a hood-mould springing from plain square-edged jambs; the arches spring directly from an impost resting on the jambs, which is frequently a simple plat-band, with the under angle chamfered off. More frequently, however, the doorways are recessed, having a nook-shaft in the angle formed by the recession, from the capital of which an archivolt springs, so that the arch in this case presents two soffits and two faces besides the hood-mould. Sometimes we have a succession of such receding arches, with a nook-shaft in each recess, from which the arches spring alternately with the projecting square-edged jambs. The depth of the doorways is owing mainly to the great thickness of the walls, but in many cases, in addition to this, that portion of the wall in which the entrance is inserted, is made to project forward

beyond the general face, the projection being finished above either with a plain horizontal capping, or with a highly-pitched gable; at St. Sepulchre's, Cambridge, the outermost arch finishes the projection, or rather the arch itself projects from the face of the wall, but this is not a common practice. With this additional thickness of walling we sometimes find as many as six or eight recessions, so that the aperture of the door occupies but a very small proportion of space, when compared with the entire surface taken up by the doorway, including the dressings. In some cases, too, the archivolt mouldings extend on each side considerably beyond the jambs. The soffits and faces of the arch, as well as those of the jambs, are sometimes left plain, but more frequently sculptured with the zig-zag, or some other ornament peculiar to the style, such as those described under *mouldings;* and to such an extent is this decoration carried, that sometimes there is not a single surface left uncovered with some ornamentation; even the shafts of the pillars are sometimes decorated in a similar manner, but this is not often the case, they are more frequently plain, and of not inelegant proportions, with capitals of various degrees of enrichment. Above the capitals is an abacus, which is often continued along the jambs from one capital to the other, but sometimes the mouldings of the archivolt are carried without interruption to the ground; occasionally, also, an enriched band is carried across the shafts and jambs, for the apparent purpose of tying them together. The hood-mould is mostly enriched, and springs from a continuation of the abacus, but if not, is either returned horizontally as a string-course, or terminates on either side in a grotesque head. The aperture often follows the form of the arch, having a semicircular head, but is very frequently square-headed, having a semicircular tympanum of masonry above, which is generally enriched with sculpture, sometimes in a sort of diaper pattern of reticulated or scalloped work, but more usually representing, in low relief, some portion of scriptural or traditionary history. Not unfrequently the head of the aperture is in the form of a square-headed trefoil, and sometimes of a segment of a circle larger than that of the external arch. Over some doorways is to be found a small niche containing a rudely sculptured figure, and sometimes a Vesica Piscis is substituted for the sculptured subject in the tympanum under the arch.

A great many examples of Norman doorways still remain, even in churches which present no other features of this style, for it seems to have been a practice with the architects of later periods to preserve this portion of an old church, even when they rebuilt the entire structure in a later style; many of them are certainly very rich and beautiful, and their preservation does credit to the taste and judgment of succeeding ages.

In this style, *windows* form but subordinate members of an edifice, and in the earlier examples are small and insignificant, being little better than slits or narrow oblong apertures, often not exceeding a few inches in breadth, and finished with a plain semicircular head; the glass was inserted close to the external wall, and the sides of the aperture were splayed towards the interior, the circular heads being generally concentric on both sides of the wall; the height of such windows was usually little more than twice their breadth, but occasionally they were much longer in proportion. In cathedral and the larger churches we sometimes find windows of much greater dimensions. After a time, a slight degree of enrichment came to be added in the shape of zig-zag and other mouldings round the arch; and at a still later period, an important improvement was made by inserting nook-shafts in the jambs, similar to those in doorways; but in this case they seldom exceeded two in number, that is to say, one on either side; in Normandy, we have examples of a greater number, which add considerable importance to the window, but we do not know of any such in this country. Such shafts were mostly slender, with plain caps and abacus, and in such examples the archivolt was either moulded or recessed, so as to form two soffits; the zig-zag moulding was very common in this position. Windows of this kind were usually larger than the earlier ones, though not always so; they are also frequently protected by a hood-mould, and the same decoration is sometimes observed in the interior.

A window of still more advanced character is very often found in the upper stories of towers; it consists of two lights with semicircular heads, separated by a central shaft, and having a jamb-shaft on either side; the two lights are enclosed under another larger semicircular arch, the spandrel of which, however, is very rarely, if ever, perforated; the larger arch is surrounded by a hood-mould. These windows bear a remarkable resemblance to those of the Byzantine and Lombardic styles, many of which exist in Italy. Sometimes, apertures for windows are pierced in a continuous arcade, running along the church; and in that case, the apertures usually occur in regular order, the intermediate arcades being left blank.

Plain circular windows, of small dimensions, are sometimes seen in clere-stories and other positions; and in churches of a late date, are to be found occasionally in gable walls, larger windows of the same form, with small shafts radiating from the centre, connected at the circumference by small semicircular or trefoiled arches; a fine example exists at Barfreston, Kent.

Of *mouldings*, such as are distinguished by their profile, the most usual combinations are composed of plain surfaces, or bands, chamfers, and quarter, half and three-quarter cylindrical mouldings, but of ornamental bands of sculpture, which are employed as mouldings in this style, there are a great variety; amongst the most common of which we may mention the following:—

The *zig-zag* is formed of a series of salient and re-entrant angles, recessed or otherwise carved on the surface of the stone, sometimes in a single line, but perhaps more frequently in two, three, or more lines, running parallel to each other, but sometimes we find them reversed. The name will probably give a better idea of the moulding than any definition; it is also termed the chevron-mould. It is used more than any other enrichment, and is found in all situations.

Similar to this is the *indented* or *trowel-point*, which presents such an appearance as a stuccoed wall which has been indented with a trowel-point before setting, the point having been pressed further into the mass, than the wider portion of the blade.

The *beak-head*, *bird's-head*, and *cat's-head* mouldings, are of a similar character, and consist of a series of grotesque heads, somewhat similar to those of the animals whose names they bear, each being furnished with a pointed beak; they are set in close proximity to each other, frequently over one or more plain mouldings, with the beaks all pointing downwards.

The *nail-head* is composed of a row of shallow pyramids, similar to nail-heads, set in contact with each other; they probably originated the idea of the dog-tooth moulding, so common in the succeeding style.

The *billet*-moulding, of which there are two kinds, the square and cylindrical, consists of cubes or semi-cylinders, placed at short intervals from each other, on a plain surface.

The alternate billet is formed of two or more rows of billets, the billets and spaces alternating in each row. The

square billet is often used for supporting a blocking-course, and is termed also the *corbel-bole*.

The *double cone* is formed of a series of two cones set base to base, and point to point, in a hollow moulding.

The *embattled* is formed of a band or channel following the form of a battlement, with alternate merlons and embrasures. Similar to this is the *dove-tail*, but in this the angles are acute, instead of right. There are several varieties of frets, trellis, and interlacing bands employed as mouldings, some plain, and others more or less enriched.

The *nebule*-moulding presents a wavy outline, and the *scalloped* such as its name implies. The *pellet* or *stud*-moulding is enriched with flat and slightly projecting circular pellets in close proximity, or at short intervals; while the *chain*, *star*, *medallion*, and *lozenge* mouldings are of a similar description, varying only in the forms of their respective ornaments.

The *cable*-moulding bears the appearance of a cable placed in a concave moulding.

The above are some of the most usual forms, but there are altogether such a variety of shapes and combinations, that it is impossible to describe them all.

The *string-courses* are very simple, consisting most frequently of a sloping water-table at top, with a plain vertical face splayed off at the lower edge; sometimes the vertical face is enriched with the zig-zag, indented, or other ornament, and occasionally a round moulding is introduced.

The *parapets* are usually plain and slightly projecting, supported upon *corbel-tables*, which consist either of cubical blocks placed at regular intervals under the parapet, and carved into grotesque heads and other devices, or of a series of small arches resting on such blocks; the arches are either semicircular, interlacing, or trefoiled. Sometimes the arches are seen without the blocks, and at others the table consists of a projecting course, the soffit of which presents a nebulous or undulating outline.

Buttresses can scarcely be said to exist in buildings of this style, the thickness and solidity of the walls not requiring such supports; somewhat similar, however, in appearance, are those projections which are termed by Mr. Whewell, *pilaster-strips*. They are precisely of the same character as the projections in Lombardic buildings, and resemble a broad flat pilaster, standing out but slightly from the general face of the wall, and terminating under the cornice or parapet, sometimes with a slope, but frequently carried up square to the soffit of the parapet, the face of the buttress being flush with that of the corbel-table. The basement consists merely of a ground-table, and the pilaster is often divided into two or more stages by string-courses, which are frequently continued along the walls, and over the arches of apertures, sometimes, however, they stop at the buttresses, and in such cases, the latter are merely plain projecting strips, without any divisions; it is seldom that the lower stages project beyond the upper ones, as in the later styles. The string-courses are mostly plain, with the under edge chamfered, or of a semi-hexagonal projection, but they are occasionally hatched or chevroned. At a later period, the angles of the buttresses are ornamented with slender nook-shafts.

The *towers* of this period are low and massive, with but little ornamentation, especially in the smaller churches. In many examples, the lower stages are plain, but the upper ones enriched with blank arcades, or with an arcade, some of the arches of which are blind, and others pierced for windows. The windows in the lower stages were quite plain, but in the higher stories, besides the arrangement just alluded to, we often see windows of two lights with semicircular heads, both included under a larger arch; the lights were divided by a central shaft, and flanked by a nook-shaft on either side. The towers are often divided into stories by string courses, and terminated at the top with a corbel-table supporting a plain horizontal parapet or blocking-course. Towers were probably roofed with low pyramidal caps of masonry, tiles or shingles, in the latter cases with projecting eaves; wooden spires covered with lead, would seem also to have been occasionally employed. Sometimes a pinnacle adorned each angle of the tower.

The plans were mostly square, having in some cases a square or circular stair-turret at one of the angles; round towers, however, of this date, are frequent in the counties of Norfolk and Suffolk. They are mostly constructed of flint, and batter externally from the base upwards; they are sometimes divided into stages by string-courses, and the upper story is more enriched than those below. The windows in the lower stories are small and narrow, and exceedingly plain.

The *pinnacles* were usually cylindrical in plan, and covered with a conical capping, but occasionally the capping was polygonal or square on the plan.

Porches, as we before stated, rarely occur in this style, some few however do remain, but mostly belonging to the larger churches. They are most frequently vaulted, and sometimes consist of two stories having a small apartment above the porch properly so called. There are sometimes benches on either side, and the walls on the interior are ornamented with blank arcades. The doorways are often deeply recessed and of an ornamental character.

The *Roofs* of this period in large buildings are highly pitched, but in the smaller churches they are somewhat more depressed, forming a rectangle at the apex. In the interior they are most frequently vaulted, although we have some examples still remaining of timber roofs: there is one at Peterborough cathedral, which is flat, and covered with paintings of figures, which have recently been restored. A greater number of roofs of this material in all probability existed, but, from their liability to decay and destruction by other means, very few examples still remain. All wide spans, such as the naves of churches, and especially of the larger ones, were probably covered with timber roofs, as the builders of the period do not seem to have been bold enough to attempt vaulting over wide intervals: this circumstance is supposed to account for the narrowness of the aisles, which, together with crypts, porches, and other places where the bearings were inconsiderable, were always vaulted. Many examples of stone vaulting still remain, the quadripartite, or that consisting of four cells, with diagonal groins, being the most common; the barrel vault, however, was also employed, a specimen of which is to be seen in the Tower of London. At first the groins were simple arrises without any projecting moulding, but afterwards a square moulding was added, and still later this simple form was enriched by cylindrical mouldings of various projections, and sometimes with the zig-zag and other ornamental mouldings.

The later portion of this style, which has been named by some the *transition*, and by others the *Semi-Norman* style, may be said to have commenced a little before the middle of the twelfth century, and forms the connecting link between the Romanesque and Pointed styles. It is distinguished generally by its amalgamation of Norman details with the pointed arch, or perhaps we should rather say by the introduction of the pointed arch into what would otherwise be Norman work.

Pointed *arches* are found treated in all respects in the same manner as the older semicircular form, having only one or two recessions on the soffit, and these generally square at the

edges without chamfering; sometimes we see only one soffit with plain chamfered edges, and not unfrequently the faces of the arch are adorned with zig-zag and other mouldings of purely Norman character. These are supported upon massive Norman piers, either cylindrical or of other form, sometimes square with attached circular shafts on the sides, but occasionally consisting of several shafts clustered together, and banded about midway between the base and capital: this last forms a near approach to the clustered pillars of a later style. The abacus was in almost all cases, square, and of Norman character, as also were the bases, but the capital frequently exhibits a more chaste and delicate ornamentation, consisting of foliage which bears some approach in design to the Early English.

The *doorways* are recessed similar to Norman examples, but have pointed arches, and the shafts with their capitals are more delicate than in pure Norman work. The arches, however, are decorated with mouldings which are purely Norman.

The *windows* generally retain the same character as before, but occasionally the pointed arch is introduced here also. In churches of this period, we frequently find a triforium with a semicircular arcade, and a clere-story with purely Norman windows ranging above an arcade composed of pointed arches; as also a lower tier of mural arcades with pointed arches surmounted by semicircular or intersecting arcades. In short, the architecture of this period is nothing more than a combination of the pointed arch with work which is otherwise Norman: it is true, the character of the arch did, in some cases, affect some other members of the building, but not to any great extent, for the main features of the style, with this exception of the arch, still remain strictly and unmistakably Norman.

During the whole of the period we have been considering, architecture was making rapid progress in England, and a number of churches and other edifices were erected.

The prelates in the early Norman reigns were men of consummate skill in architecture; they applied themselves to the rebuilding of cathedral churches, and also the rebuilding of the greater abbeys. No less than fifteen of the twenty-two English cathedrals retain considerable portions which are undoubtedly Norman workmanship, and of which the several dates are ascertained. The Normans, who either were architects themselves, or under whose auspices architecture flourished, are Gundulph, Bishop of Rochester, who flourished from A.D. 1077 to 1107; Mauritius, Bishop of London, who flourished from 1086 to 1108; Roger, Bishop of Salisbury, from 1107 to 1140; Ernulf, Bishop of Rochester, from 1115 to 1125; Alexander, Bishop of Lincoln, from 1123 to 1147; Henry of Blois, Bishop of Winchester, from 1129 to 1169; and Roger, Archbishop of York.

The works of Gundulph may be seen at Rochester, Canterbury, and Peterborough. Mauritius, of London, built Old St. Paul's cathedral; Roger, of Salisbury, the cathedral of Old Sarum; Ernulf completed the work begun by Gundulph at Rochester; Alexander, of Lincoln, rebuilt his own cathedral: and Henry of Blois, Bishop of Winchester, a most eminent architect, built the conventual churches of St. Cross and Rumsey, in Hampshire; but with respect to Roger, Archbishop of York, none of his works remain.

By these architects, the Norman style of architecture was progressively brought to perfection in England; and it will be easily supposed, that the improvements made by any of them were only adopted in succession.

Many of the churches belonging to the greater abbeys were constructed in this æra; but of these, few, indeed, have escaped the general demolition that took place at the Reformation.

With respect to the military structures of the Normans they knew they could not live in security without building strong places of defence; they therefore erected a castle upon every lordship, or assimilated with their own, what they found already erected to their hands.

The leading distinction in a Norman fortress, is a lofty mound of earth thrown up in the centre of the other works, from the excavations necessary in forming the ditch, fosse, or moat. A square or circular tower, consisting of several stories, rose from the upper ballium, or a low circular story of considerable diameter, which was usually approached by a very steep stone staircase on the outside.

The gateway, or tower of entrance, and the barbican, or watch-tower, had both of them a communication with the keep. Remarkable instances in the square form are those of the towers of London, Norwich, Rochester, Dover castle, Hedingham (Essex,) Bamborough (Northumberland,) Porchester, Colchester, Kenilworth, Knaresborough, Carisbrooke, and Oxford. Of the circular are Arundel, Pontefract, and Conisburgh (Yorkshire,) Lincoln, and Tunbridge in Kent. Besides the above-stated towers, an irregular form, of which the plan consists of several segments of circles, may be seen in Clifford tower, in York, and Berkeley castle, Gloucestershire. These keeps, or citadels, in subsequent æras underwent no alteration, whatever additions or improvements took place in architecture.

Bishop Gundolph seems to have considered the lofty artificial mound, originally of Danish usage, as unnecessary. His central towers are so lofty as to contain four stories, as was also the case with most other keep-towers. The basement was the dungeon, without light: the portal or grand entrance was raised many feet above the ground; but his great merit consisted in various architectural contrivances, by which as much security during a siege was given to his keeps by stratagem, as by real strength. The walls were not unfrequently from 12 to 20 feet thick at the base. In the souterrain of the vaulted stone, the military engines and stores were deposited. In the thickness of the walls were placed winding staircases, the well for water, the vast oven, enclosed galleries and chimneys, with an aperture open to the sky, and communicating with the dungeon, in which prisoners were confined, and to whom it gave all the light and air they could receive. There was also a kind of flue for conveying sound to every part, not more than eight inches in diameter. The state apartment occupied the whole third story, and the staircases leading to it were much more commodious than the others, and even so large as to admit of military engines. Adjoining to the great chamber was the oriel, lighted by a window embowed withinside. In Rochester castle the chief room was 32 feet high, including the whole space within the walls. The walls of the ground story had no light, the second had only loop-holes; but the third had large arched windows placed so high as not to be looked through, and so defended by an internal arcade that no missile weapon could enter or fall with effect. Each floor had its communication with the well. The chimneys were very capacious, projected considerably into the rooms, and rested upon small pillars; and the sinks were so contrived, in an oblique direction, that no weapons could be sent up them.

Gundulph is said to have introduced the architectural ornaments of the ecclesiastic style into fortresses, both withinside and without. Most of the Norman castles had a richly carved door-case or portal, as the remains of Arundel and Berkeley amply testify. The windows were decorated with mouldings, frequently sculptured. Castle-Rising, Norfolk, and Norwich abound in admirable specimens of Norman arcades and mouldings.

The great tower of entrance was built at the foot of the artificial mount, from which was a sally-port, with stone stairs leading to the keep. It contained the portcullis and drawbridge affixed to the archway, and several spacious chambers. In point both of the formation of the mount and keep, and their connection with the entrance-tower, the remains of Tunbridge, and the more perfect state of Arundel castle, exhibit a singular resemblance. The walls were protected by strong buttresses, and the round towers had a central space left open, to admit light and air. At Arundel, the corbel-stones, which supported the beams of timber, are still to be seen. See CASTLE.

The well-authenticated buildings of Norman construction, erected from before A. D. 1100 to 1150, are the abbeys of Abingdon, Reading, and Cirencester, destroyed; Malling, Kent; Tewkesbury, nave, aisles, transept, and west front; Malmsbury, nave and west front; Buildwas, Salop; St. Botolph, Colchester; Bolton, Yorkshire; Winborn minster, Dorsetshire; Castle-Acre, Norfolk; Dunstable, Bedfordshire; St. Cross, Hants; Romsey, Hants; Furness, Lancashire, the most ancient parts; Llindisfarne, Northumberland; Byland, Yorkshire; Lanercost, Cumberland; Sherbourn, Dorset; Southwell, Nottinghamshire; Kirkstall, Yorkshire, nave. Of those now named Tewkesbury, Malmsbury, Winborn minster, St. Cross, Romsey, and Sherbourn, are now used as parochial churches.

From A. D. 1155, the style of architecture practised by the Normans began to be mixed with new forms and decorations, and was at length superseded by that much more elegant and lofty style of building, improperly denominated *Gothic.*

The principal works that may be consulted in Norman architecture, are the *Archæologia*, Carter's *Ancient Architecture of England*, Britton's *Architectural Antiquities of Great Britain*, and Dalaway's *English Architecture.*

NOSINGS OF STEPS, the projecting parts of the tread-board or cover, which stand before the riser. The nosings of steps are generally rounded, so as to have a semicircular section, and, in good staircases, a hollow is placed under them.

NOTCH-BOARD, a board notched or grooved out, to receive and support the ends of the steps of a staircase.

NOTCHING, the cutting of an excavation throughout the whole breadth of a substance.

By this method timbers are fastened together; or their surfaces, when joined at angles, are made to coincide.

NUCLEUS (Latin) the internal part of the flooring of the ancients, consisting of a strong cement, over which they laid the pavement, bound with mortar.

NUEL, see NEWEL and STAIRCASE.

NUISANCE, or NUSANCE, (from the French, *nuire*, to hurt) in law, is used not only for a thing done to the hurt or annoyance of another, in his free lands or tenements, but also for the assize, or writ lying for the same.

Nuisances are either *public* or *private:* a *public* or *common* nuisance is an offence against the public in general, either by doing what tends to the annoyance of all the king's subjects, or by neglecting to do what the common good requires. A *private* nuisance is when only one person or family is annoyed, by the doing of anything; as where a person stops up the light of another's house, or builds in such a manner, that the rain falls from his house upon his neighbour's; as likewise the turning or diverting water from running to a man's house, mill, meadow, &c., corrupting or poisoning a water-course, by erecting a dye-house, or a lime-pit, for the use of trade, in the upper part of the stream; stopping up a way that leads from houses to lands; suffering a house to decay, to the damage of the next house; erecting a brew house in any place not convenient; or a privy, &c., so near another person's house as to offend him; or exercising any offensive trade; or setting up a fair or market, to the prejudice of another.

The continuation of a nuisance is by the law considered as a new nuisance, and therefore, where a person suffers a nuisance to be set up, and then alienates and lets the land, &c., without removing it, an action of the case lies against him who erected it; and also against the alienee or lessee, for continuing it.

Writs of nuisance are now properly termed *trespasses* and *actions upon the case.*

NUISANCE, *Abatement of* denotes the removal of it, which the party aggrieved is allowed to do, so as he commits no riot in the doing of it.

"If a house or wall is erected so near to mine, that it stops my ancient lights, which is a *private* nuisance, I may enter my neighbour's land, and peaceably pull it down." *Salk.* 459. "Or if a new gate is erected across the public highway, which is a *common* nuisance, any of the king's subjects passing that way may cut it down, and destroy it." *Cro. Car.* 184. The reason why the law allows this private and summary method of doing one's self justice, is, because injuries of this kind, which obstruct or annoy such things as are of daily convenience and use, require an immediate remedy; and cannot wait for the slow progress of the ordinary forms of justice.

O.

OAK

OAK, the well-known tree, styled by way of eminence the "lord of the forest." The oak grows to an enormous size, attaining frequently a height of from 80 to 100 feet, with a trunk from 6 to 12 feet or more in circumference. Some of the parks attached to the mansions of our great nobles are adorned with magnificent specimens of these monarchs of the woods. In Amphill Park stands an oak of very large size. The circumference of its base is upwards of 40 feet; its middle girt is about 30; it is quite hollow, forming a concavity sufficient to contain four or five middle-sized persons standing together withinside. The chief of its branches, which is much greater in dimensions than many parent oaks, is supported by a couple of large wooden props, on account of its weight being too great to be kept up by the main body of the tree. There are many fine oaks in numerous other parts of the empire; as in Salcey forest, Northamptonshire, and in the Duke of Hamilton's park in Lanarkshire. The wood of this tree is the most durable that grows, and its use in naval and domestic purposes is exceedingly great.

There are several kinds of oak timber used in this country but none are equal to the common British oak, which is more durable than any other wood attaining the same size. The oak imported from America is very inferior to that of

England; the oak from the central parts of Europe is also inferior, especially in compactness and resistance of cleavage. The knotty oak of England, when cut down at a proper age, (from fifty to seventy years,) is the best timber known, for at once supporting a weight, resisting a strain, and not splintering by a cannon-shot; hence its value in ship-building.

OASIS, is the appellation given to those fertile spots, watered by springs and covered with verdure, which are scattered about the great sandy deserts of Africa. In Arabic they are called wadys. The Arabic and the Greek name seem to contain the same root, and possibly the word may be originally a native African term. The most noted are in the Libyan desert, namely, Angila, Siwah, the great oasis west of Thebes, or El Khargeh; the little oasis, or Wah el Bahryeh, and several smaller ones, which are noticed under Egypt. Fezzan also may be considered as a great oasis of the Sahara. Hornemann has described Fezzan; Brown has given an account of the oasis of El Khargeh, and Cailliaud of the smaller oases west of Egypt.

The oases appear to be depressions in the table-land of Libya. On going from the Nile westward, the traveller gradually ascends till he arrives at the summit of an elevated plain, which continues nearly level, or with slight undulations, for a considerable distance, and rises higher on advancing towards the south. The oases are valleys sunk in this plain, and when you descend to one of them you find the level space or plain of the oasis similar to a portion of the valley of Egypt, surrounded by steep hills of limestone at some distance from the cultivated land. The low plain of the oasis is sand-stone or clay, and from this last the water rises to the surface and fertilizes the country; and as the table-land is higher in the latitude of Thebes than in that of Lower Egypt, we may readily imagine that the water of the oases is conveyed from some elevated point to the south, and being retained by the bed of clay, rises to the surface wherever the limestone superstratum is removed.

OBELISK, (from the Latin, *obeliscus*,) a quadrangular pyramid, very slender and high; raised as an ornament in some public place, or to show some stone of enormous size; and frequently charged with inscriptions and hieroglyphics.

Borel derives the word from the Greek, *οβιλος*, *a spit, broach, spindle*, or even a kind of *long javelin*. Pliny says, the Egyptians cut their obelisks in form of sunbeams; and that, in the Phœnician language, the word *obelisk* signifies *ray*.

The Egyptian priests called their obelisks the *sun's fingers;* because they served as styles, or gnomons, to mark the hours on the ground. The Arabs called them *Pharaoh's needles;* whence the Italians call them *aguglia;* and the English *Cleopatra's needles*. *See* Cleopatra's Needles.

The difference between obelisks and pyramids, according to some, consists in this, that the latter have large bases, and the former very small ones, compared with their height; though Cardan makes the difference to consist in this, that obelisks are to be all of a piece, or consist of a single stone; and pyramids of several.

The proportions of the height and thickness are nearly the same in all obelisks; that is, their height is nine, or nine and a half, sometimes ten times their thickness; and their thickness, or diameter, at top, is never less than half, nor greater than three-fourths, of that at bottom.

This kind of monument appears to have been very ancient; and, we are told, was first made use of to transmit to posterity the principal precepts of philosophy which were engraven on them in hieroglyphic characters. In after-times they were used to immortalize the actions of heroes, and the memory of persons beloved.

The first obelisk we know of was that raised by Rameses, king of Egypt, in the time of the Trojan war. It was 40 cubits high, and, according to Herodotus, employed 20,000 men in building. Phius, another king of Egypt, raised one of 45 cubits; and Ptolemy Philadelphus another, of 88 cubits, in memory of Arsenoë. *See* Porphyry.

Augustus erected an obelisk at Rome, in the Campus Martius, which served to mark the hours on an horizontal dial drawn on the pavement.

F. Kircher reckons up fourteen obelisks, celebrated above the rest, viz., that of Alexandria, that of the Barberins, those of Constantinople, of the Mons Esquilinus, of the Campus Flaminius, of Florence, of Heliopolis, of Ludovisio, of St. Mahut, of the Medici, of the Vatican, of Mount Cælius, and that of Pamphylia.

One of the uses of obelisks among the ancients was, to find the meridian altitudes of the sun at different times of the year. Hence they served instead of very large gnomons. One of the obelisks now standing at Rome, that of St. John's Lateran, is in height 108 English feet, without the pedestal; and the other obelisk, brought to Rome by Augustus, buried under the Campus Martius, wants but little of the same height. Pliny gives a description of this gnomon, lib. xxxvi. sect. 15. From him it appears, that there was laid down, from the foot of the obelisk northward, a level pavement of stone, equal in breadth to the breadth of the obelisk itself, and equal in length to its shadow at noon, upon the shortest day; that is to say, that its length was to the height of the obelisk, almost as 22 to 10, and that under this pavement, there were properly let in parallel rulers of brass, whose distance from the point, directly under the apex of the obelisk, were perfectly equal to the length of the shadow thereof at noon, on the several days of the year, as the same lengths decreased from the shortest day to the longest, and again increased from the longest day to the shortest. Vide *Phil. Trans.* No. 482, art. 5, vol. xliv. p. 365; where we also find some remarks by Mr. Folkes on Hardouin's *Amendment of a Passage in Pliny's Natural History*, lib. ii. sect. 74, about the length of the shadows of gnomons in different latitudes.

OBLIQUE LINE. When one straight line stands upon another, and makes unequal angles therewith, the angles are said to be *oblique*, the one being greater than a right-angle, and the other less. Hence a line is only oblique, as it relates to another line: without this distinction, the word would be destitute of meaning.

Oblique Angle, one that is greater or less than a right angle.

Oblique-angled Triangle, one that has no right angle.

Oblique Arches, are those which conduct high roads across a river, canal, open drain, &c., in an oblique direction. —Oblique arches are otherwise called *skew bridges*. *See* Bridge Arch.

OBLONG (from the Latin *oblongus*) a rectangle of unequal dimensions.

OBSERVATORY, or Observatorium, a place destined for observing the heavenly bodies; or a building usually in form of a tower, raised on some eminence, and covered with a terrace for making astronomical observations. The more celebrated observatories are, 1. The Greenwich Observatory, or Royal Observatory of England, was built in 1676, by order of Charles II. at the solicitation of Sir Jonas Moore and Sir Christopher Wren, and furnished with the most accurate instruments by the same, particularly a noble sextant of seven feet radius, with telescopic sights. The province of observing was first committed to Flamsteed, a man who

seemed born for the employment. For fourteen years, with unwearied pains, he watched the motions of the planets, and particularly those of the moon, as he had been instructed; that a new theory of that planet being found, exhibiting all her irregularities, the longitude might thence be determined. In the year 1690, having provided himself with a mural arch of seven feet diameter, well fixed in the plane of the meridian, he verified his catalogue of the fixed stars, (which hitherto had depended altogether on the distances measured with the sextant,) after a new and very different manner, viz., by taking the meridian altitudes, and the movements of culmination, or the right ascension and declination. With this instrument he was so pleased, that he laid the use of the sextant almost wholly aside; and in this way was the astronomer-royal employed for thirty years; in the course of which time nothing had appeared in public worthy so much expense and preparation; so that the observer seemed rather to have been employed for his own sake, and that of a few friends, than for the public; though it was notorious, the observations that had been made were very numerous, and the papers swelled to a great bulk. This occasioned Prince George of Denmark, in 1704, to appoint certain members of the Royal Society, viz., the Hon. Fr. Robarts, Sir Christopher Wren, Sir Isaac Newton, Dr. Gregory, and Dr. Arbuthnot, to inspect Flamsteed's papers, and select such as they should think fit for the press, purposing to print them at his own expense, but the prince dying before the impression was half finished, it lay still for some time; till at length it was resumed by order of Queen Anne, and the care of the press committed to Dr. Arbuthnot, and that of correcting and supplying the copy to Dr. Halley. Such was the rise and progress of the "Historia Cœlestis," the principal part whereof is the catalogue of fixed stars, called also the Greenwich Catalogue. Flamsteed was succeeded by Dr. Halley; and Dr. Halley, in 1742, by Dr. Bradley, so deservedly celebrated for his discovery of the aberration of the stars, and the mutation of the earth's axis; after Dr. Bradley, the appointment was, in 1762, conferred upon Mr. Bliss, who was succeeded in 1785 by Dr. Maskelyne, the late worthy astronomer-royal; upon whose demise, in 1811, this important office was conferred upon Mr. Pond.

The Greenwich observatory is found, by very accurate observation, to lie in 51° 28′ 30″ north latitude.

2. The French Observatory, built by Louis XIV. in the Fauxbourg St. Jacques, Paris, is a very singular, but withal, a very magnificent building. It is eighty feet high, and at the top there is a terrace. It is here M. de Lahire, M. Cassini, &c., were employed. This observatory was begun in 1664, and finished in 1672. The difference in longitude between this and Greenwich Observatory is 20° 20′ 15″ each. In the Paris Observatory, is a cave, or cellar, of 170 feet descent, for making various experiments, particularly such as relate to congelations, refrigerations, indurations, conservations, &c. And in this cave there is a thermometer of M. de Lahire, which is always at the same height, indicating the temperature of the place to be always the same.

3. Tycho Brahe's observatory in the little island of Ween, or the Scarlet Island, between the coasts of Schonen and Zealand in the Baltic, was erected and furnished with instruments at his own expense; and was called by him Uranienburgh. In this place, he spent twenty years in observing the stars.

We may enumerate here some other observatories, as that of Pekin, erected by a late emperor of China in his capital, upon the recommendation of the Jesuit missionaries; and that of the Brahmins at Benares, in the East Indies, of which we give the following description:—

The observatory at Benares, built by order of the emperor Akbar, was once a magnificent structure; the lower part of it is now, however, converted into stables; the court-yards and apartments are still spacious. It stands on the banks of the Ganges, and the summit is approached by a staircase leading to a large terrace, where numerous instruments still remain in great preservation; stupendously large, immoveable from the spot, and built of stone, some of them being upwards of twenty feet in height. Their graduation is very exact.

OBTUNDING, (from the Latin *obtundo*,) the blunting or taking away a sharp corner.

OBTUSE, (from the Latin) anything that is blunt.

Obtuse-angled Triangle, a triangle which has an obtuse angle.

Obtuse Section of a Cone, a name given to the hyperbola, by ancient geometricians, because they considered it only in such a cone, whose section through the axis was an obtuse-angled triangle.

OCHRE, in painting, a colour prepared from a species of earth, also termed ochre, composed of fine, soft, smooth, and argillaceous particles, slightly coherent, rough to the touch, and easily diffusable in water; ochre is of various colours. Yellow is the most prevalent, but there are red, green, blue, and black ochres. The colouring matter of ochre is almost always oxide of iron. Red chalk is much used for drawing; for this purpose, it should be free from grit, and not too hard. In order to free it from grit, and render it better for use, it is sometimes pounded, washed, mixed with gum, and cast into moulds of convenient shape and size. Under the name of reddle, this substance is much used for the marking of sheep, and, when mixed with oil, for the painting of pales, gates, and the wood-work of out-buildings.

OCTAGON, (from *ὀκτω*, *eight*, and *γωνία*, *sides*) a figure of eight sides, and consequently as many angles. When all the sides and all the angles are equal, the figure is called *a regular octagon*.

OCTAHEDRON, or Octaedron, (Greek, *ὀκτάεδρος*) in geometry, one of the five regular bodies, consisting of eight equal and equilateral triangles.

The octahedron may be conceived as consisting of two quadrilateral pyramids put together at their bases.

Its solidity, therefore, is had by multiplying the quadrangular base of either by one-third of the perpendicular height of one of them, and then doubling the product. The square of the side of an octahedron is in a subduple ratio of the square of the diameter of the circumscribing sphere. *See* Regular Body.

OCTOGON, *See* Octagon.

OCTOSTYLE, (from *ὀκτὼ*, *eight*, and *ςύλος*, *a column*) an ordonnance with eight columns. It is generally understood of columns when their axes are all in the same plane, as in the portico of the Pantheon at Rome, and the Parthenon at Athens.

ODEUM, (Greek, *ὠδειον*) among the ancients, was a place for the rehearsal of music to be sung in the theatre.

Odeum was sometimes also extended to buildings that had no relation to the theatre. Pericles built an odeum at Athens, where musical prizes were contended for. Pausanias says, that Herod, the Athenian, built a magnificent odeum for the sepulchre of his wife.

Ecclesiastical writers also use odeum for the choir of a church.

ODOMETER, an instrument for measuring the distance travelled over by a chaise or other carriage; it is attached to the wheel, and by means of an index and dial-plate, shows the distance gone over.

ŒCUS, (Greek) a word used by Vitruvius, to denote some apartment connected with the dining-room. The œci were very magnificent, as will appear by reading chapters v. and vi. book vi. of Newton's Vitruvius.

OFFICES, (French) in architecture, denote all the apartments that serve for the necessary occasions of a great house, or palace, or those where the servants are employed; as kitchens, pantries, brewhouses, confectioneries, fruiteries, granaries, &c., as also wash-houses, wood-houses, stables, &c. The offices are commonly in the *bassecour;* sometimes they are sunk under ground, and well vaulted.

OFFSETS, those planes of a wall which connect two faces in different parallel planes, where the upper part recedes from the lower.

OGEE, or O-G, in architecture, a moulding, consisting of two members, the one concave, the other convex, the same with what is otherwise called *cymatium.*

Vitruvius makes each member of the ogee a quadrant of a circle; Scammozzi, and some others, make them somewhat flatter, and strike them from two equilateral triangles.

The figure of an ogee bears some resemblance to that of an S.

OGIVES, in architecture, arches or branches of a Gothic vault, which, in lieu of being circular, pass diagonally from one angle to another, and form a cross with the other arches which make the side of the squares, whereof the ogives are diagonals.

The middle, where the ogives cut or cross each other, is called the *key*, which is sometimes carved in form of a rose, or a *cul de lampe.* The members or mouldings of the ogives are called *nerves*, *branches*, or *reins;* and the arches which separate the ogives, *double arches.*

OILLETS, Oillettes, or Oylets, (from the French *œil*, an eye). Eyelet-holes, small openings, or holes of various forms in the walls of fortified places, through which missiles were discharged on the besiegers.

OLD RED SANDSTONE, in *geology*, the lowest member of the carboniferous group of strata, extensively developed in the counties of Shropshire and Herefordshire, in England; Brecknockshire, in Wales; and Dumfrieshire and Forfarshire in Scotland. It lies between the carboniferous series and the silurian rocks. It consists of many varieties and alternations of silicious sandstones, and conglomerates of various colours, red predominating. According to Bakewell, the old red sandstone is a graywacke, coloured red by the accidental admixture of oxide of iron.

OLYMPIAN GAMES, the chief of the four great national festivals of the Greeks, were celebrated at Olympia, a sacred spot on the banks of the Alpheus, near Elis, every fifth year. The exact interval at which it recurred, was one of forty-nine and fifty lunar months alternately; so that it fell sometimes in the month of Appollonius (July) sometimes in the month of Parthenius (August.) The period between two celebrations, was called an Olympiad. It lasted during five days.

The Olympian festival consisted of religious ceremonies, athletic contests, and races. The chief deity who presided over it was Jupiter Olympius, whose temple at Olympia, containing the ivory and gold statue of the god by Phidias, was one of the most magnificent works of art in Greece. The games consisted of horse and foot races, leaping, throwing, wrestling, and boxing, and combinations of these exercises. The earliest of these games was the foot-race, which was the only one revived by Iphitus. The space run, was the length of the stadium in which the games were held, namely, about 600 English feet.

Wrestling was introduced in the 18th Olympiad (B.C.708). The wrestlers were matched in pairs by lot; when there was an odd number, the person who was left by the lot without an antagonist, wrestled last of all with him who had conquered the others. The athlete who gave his antagonist three throws, gained the victory. There was another kind of wrestling, in which, if the combatant who fell could drag down his antagonist with him, the struggle was continued on the ground, and the one who succeeded in getting uppermost and holding the other down gained the victory.

Boxing was introduced in the 23rd Olympiad (B.C. 688). The boxers had their hands and arms covered with thongs of leather, called cestus, which served both to defend them, and to annoy their antagonists. Virgil describes the cestus as armed with lead and iron; but this is not known to have been the case among the Greeks. In these games, the combatants fought naked.

The horse-races were of two kinds, with chariots, or without. The chariot-race was generally with four-horsed chariots, and was introduced in the 25th Olympiad (B.C. 680.) The course had two goals in the middle, at the distance probably of two stadii from each other. The chariots started from one of these goals, turned round the other, and returned along the other side of the hippodrome. This circuit was made twelve times. The great art of the charioteer consisted in turning as close as possible to the goals, but without running against them, or against the other chariots. The places at the starting-post were assigned to the chariots by lot.

There were two sorts of races on horseback, namely, that in which each competitor rode one horse throughout the course, and the other in which, as the horse approached the goal, the rider leaped from his back, and keeping hold of the bridle, finished the course on foot. *See* Circus and Hippodrome.

It seems to be generally admitted that the chief object of this festival was to form a bond of union for the Grecian states. Besides this, the great importance which such an institution gave to the exercises of the body, must have had an immense influence in forming the national character. Regarded as a bond of union, the Olympian festival seems to have had but little success in promoting kindly feelings between the Grecian states, and perhaps the rivalry of the contest may have tended to exasperate existing quarrels; but it undoubtedly furnished a striking exhibition of the nationality of the Greeks, of the distinction between them and other races. Perhaps the contingent effects of the ceremony were, after all, most important. During its celebration, Olympia was a centre for the commerce of all Greece, for the free interchange of opinions, and for the publication of knowledge. The concourse of people from all parts of Greece afforded a fit audience for literary productions, and gave a motive for the composition of works worthy to be laid before them. Poetry and statuary received an impulse from the demand made upon them to aid in perpetuating the victors fame.

ONE-PAIR-OF-STAIRS, signifies the first story, or floor, by passing up the stairs, or pair of stairs, as they are frequently called, from the entrance-floor to the next floor, which is denominated the one-pair-of-stairs floor, and frequently (though very improperly) the first floor, the entrance floor being naturally the first floor.

OOLITE. *See* Roe-Stone.

OPAE, the space, signifies the space between joists. *See* Newton's Vitruvius, book iv. chap. ii.

OPENING. *See* Aperture.

OPERA HOUSE, a theatre for the express purpose of performing operas or musical dramas.

OPISTHODOMOS, the enclosed space behind a temple. The treasury at Athens was so called, because it stood behind the temple of Minerva.

OPPOSITE ANGLES, those which are formed by two straight lines crossing each other, but not two adjacent angles.

Opposite Cones, those to which a straight line can be everywhere applied on the surfaces of both cones.

Opposite Sections, the sections made by a plane cutting two opposite cones.

OPTIC PYRAMID. *See* Perspective.

Optic Rays. *See* Perspective.

OPTICS, (from the Latin, *optica*) is properly the science of direct vision. In a larger sense, the word is used for the science of vision, or visibles in general; in which sense, optics includes catoptrics and dioptrics, and even perspective.

In its more extensive acceptation, optics is a mixed mathematical science, which explains the manner by which vision is performed in the eye; treats of sight in the general; gives the reasons of the several modifications or alterations which the rays of light undergo in the eye; and shows why objects appear sometimes greater, sometimes smaller, sometimes more distinct, sometimes more confused, sometimes nearer, and sometimes more remote. In this extensive signification, it is considered by Sir Isaac Newton, in his admirable work called *Optics*.

Optics make a considerable branch of natural philosophy; both as it explains the laws of nature, according to which vision is performed; and as it accounts for abundance of physical phenomena, otherwise inexplicable.

From optics likewise arises perspective, all the rules of which have their foundation in optics. Indeed, Tacquet makes perspective a part of optics; though John, Archbishop of Canterbury, in his *Perspectiva Communis*, calls optics, catoptrics, and dioptrics, by the common name *perspective*.

This art, for so it should be considered rather than as a science, was revived, or re-invented, in the sixteenth century. It owes its birth to painting, and particularly to that branch of it which was employed in the decoration of the theatre. Vitruvius informs us, that Agatharchus, instructed by Æschylus, was the first who wrote upon this subject; and that afterwards the principles of this art were more distinctly taught by Democritus and Anaxagoras, the disciples of Agatharchus. How they described the theory of this art we are not informed, as their writings have been lost; however, the revival of painting in Italy was accompanied with a revival of this art; and the first person who attempted to lay down the rules of perspective, was Pietro del Borgo, an Italian. He supposed objects to be placed beyond a transparent tablet, and endeavoured to trace the images which rays of light, emitted from them, would make upon it. The book which he wrote upon this subject, is not now extant; and this is the more to be regretted, as it is very much commended by the famous Egnazio Dante. Upon the principles of Borgo, Albert Durer constructed a machine, by which he could trace the perspective appearance of objects. Balthazar Parussi, having studied the writings of Borgo, endeavoured to make them more intelligible. To him we owe the discovery of points of distance, to which all lines that make an angle of 45 degrees with the ground-line are drawn. Soon after, Guido Ubaldi, another Italian, found that all the lines, which are parallel to each other and to the horizon, if they be inclined to the ground-line, converge to some point in the horizontal line; and that through this point, also, a line drawn from the eye, parallel to them will pass. These principles combined, enabled him to make out a pretty complete theory of perspective. Great improvements were made in the rules of perspective by subsequent geometricians, particularly by Professor Gravesande, and still more by Dr. Brook Taylor, whose principles are, in a great measure, new, and much more general than those of any person before him. Although Dr. Taylor really invented this excellent method of perspective, yet it is suggested by Mr. Robins, that the same method was published by Guido Ubaldi in his *Perspective*, printed at Pesaro, in 1600. In this treatise the method is delivered very clearly, and confirmed by most excellent demonstrations. In the last book, Ubaldi applies his method to the delineation of the scenes of a theatre; and in this, as far as the practice is concerned, he is followed by Signor Sabatellini, in his *Practica di Fabrica Scene*, of which there was a new edition at Ravenna in 1638; and to this was added a second book, containing a description of the machines used for producing the sudden changes in the decorations of the stage. In the catalogue of the great Sir Isaac Newton's works, at the end of his *Life*, is a work on perspective, written in Latin; *Newtoni Elementa Perspectivæ Universalis*, 1746. 8vo. We are indebted to opticians of a much later period for ingenious devices to apply the knowledge they had of optics, and especially of perspective, to the purpose of amusement.

For the principles and practice of Perspective, see that article, where they will be fully treated of.

ORANGERY, a gallery in a garden, or parterre, exposed to the south, but well closed with a glass window, to preserve oranges in during the winter season.

The orangery of Versailles is the most magnificent that ever was built; it has wings, and is decorated with a Tuscan order.

ORATORY, (from the Latin, *oratorium*, a temple,) a closet or apartment in a large house, near a bedchamber, furnished with a small altar, or an image, for private devotion, among the Romanists. The ancient oratories were little chapels adjoining to monasteries, wherein the monks offered up their prayers, before they had churches.

In the sixth and seventh centuries, oratories were little churches built frequently in burial-grounds, without either baptistry, cardinal, priest, or any public office, the bishop sending a priest to officiate occasionally.

ORB, (from the Latin *orbis*, a sphere,) a knot of flowers, or herbs, in a Gothic ceiling, placed upon the intersection of several ribs, in order to cover the mitres of every two adjoining ribs. This is otherwise called *boss*.

ORCHESTRA, in ancient theatres, a place set apart for the chorus, and in modern theatres that division in which the musicians are located. *See* Theatre.

ORDER, the perfect arrangement and composition of any architectural work; but the term is more especially used to designate the various methods of arrangement employed in Grecian or Classical architecture, and is definitely applied to such a portion of a building as may comprehend the whole design by a continuity and repetition of its parts. By those who put faith in Vitruvius, the Grecian orders are supposed to be but an imitation of the parts of a primitive hut, and which, according to his theory, originally consisted of a roof or covering, supported by posts made of the trunks of trees, in four rows, forming a quadrangular enclosure. Beams were laid upon the tops of the posts, in order to connect them, in their longitudinal direction, in one body. To support the covering, timbers were laid from beam to beam across the breadth; and to throw off the wet, other beams were laid parallel to those resting upon the posts, but jutting farther over on each side of the edifice: and these again supported inclined timbers, which overhung their supports, and formed

a ridge in the middle of the roof, for throwing off the wet; and thus the part supported formed three principal distinct portions, which, in process of time, were decorated with certain mouldings, or other ornaments, each part still preserving its distinct mass, though perhaps not exactly similar to the original form. The three parts, taken as a whole, were called *the entablature:* the lower part, consisting of the linteling beams, was called *the epistyle*, or *architrave:* the middle part, which receded from the epistyle, was called *the zoophorus*, or *frieze;* and the upper part, which projected considerably over the frieze, being in imitation of the ends of the roof, was called *the cornice.*

Therefore the entablature consists of a cornice, frieze, and architrave.

The posts received the name of *columns*, which always consist of two principal divisions at least, and frequently of three. The columns were ornamented at the top in imitation of the stones laid upon the posts in the original wooden hut, for throwing off the rain. These decorations at the top received the name of *capital*, and each of the wooden posts that of *shaft.*

When ornaments were added to the foot of the shaft, they were termed *the base.*

The order, therefore, consists principally of a column and entablature. The column is subdivided into a shaft and capital, or, at most, into three principal parts, a base, shaft, and capital; and the entablature, as has been observed, into architrave, frieze, and cornice. These parts are again divided into smaller portions, termed *mouldings*, or other ornaments. *See* ARCHITECTURE, ORDERS OF.

ORDER, *Attic*, the pilaster of an attic. *See* ATTIC.

ORDER, *Caryatic*, that in which the entablature is supported by women instead of columns. *See* CARYATIC.

ORDER, *Gothic*, the pointed style of architecture, usually called *Gothic. See* ARCHITECTURE, CASTLE, and GOTHIC.

ORDERS, *Greek*, are the Doric, Ionic, and Corinthian. *See* each of these articles.

ORDER, *Persian*, that where the entablature is supported by men instead of columns. The history is related in Newton's *Vitruvius*, book i. chap. i. page 3. *See* PERSIANS.

ORDER OF TEMPLES, otherwise called SPECIES, are the amphiprostyle, the antæ, the dipteral, the peripteral, and the prostyle. *See* those respective articles.

ORDINANCE, or ORDONNANCE, the same as ORDER: which see.

ORDINATES, in geometry and conics, are lines drawn from any point of the circumference of an ellipsis, or other conic section, perpendicularly across the axis, to the other side.

The Latins call them *ordinatim applicatæ.*

The halves of each of these are properly only *semi-ordinates*, though popularly called *ordinates.*

The ordinates of a curve may more generally be defined to be right lines parallel to each other, terminated by the curve, and bisected by a right line called the *diameter.* In curves of the second order, if any two parallel right lines be drawn so as to meet the curve in three points, a right line, which cuts these parallels, so as that the sum of two parts terminating at the curve on one side the secant, is equal to the third part terminated at the curve on the other side, will cut all other right lines parallel to these, which meet the curve in three points, after the same manner, *i. e.* so as that the sum of the two parts on one side will always be equal to the third part on the other side. And these three parts, equal on either side, Sir Isaac Newton calls *ordinatim applicatæ*, or ordinates of curves of the second order.

ORDINATE, in an ellipsis, hyperbola, and parabola. *See* the respective articles.

ORGANICAL DESCRIPTION OF CURVES, a method of describing curves upon a plane by continued motion.

ORIEL WINDOW, in architecture, a projecting angular window, mostly of a triagonal or pentagonal form, and divided by mullions and transomes into different bays and other compartments. These windows are not peculiar to the pointed style, as they are of frequent occurrence in the barbarous style which succeeded it. During the reigns of Elizabeth and James I. they became still more common than they had been before in the pointed style.

ORLE (French, formed from the Latin *orletum* or *orlum*, of *ora*, a border or list) a fillet under the ovolo or quarter-round of a capital.

When at the top or bottom of the shaft, it is called *cincture.*

Palladio also uses orle for the plinth of the bases of the columns and pedestals.

ORNAMENTS (from the Latin *ornamentum*, to embellish) in architecture, all the sculpture, or carved work, with which a piece of architecture is enriched.

Plate I. Some of the most beautiful specimens of ornaments, in scrolls and branches, used in the capitals of columns, in Grecian and Roman antiquity.

Figures 1, 2, 3, 4, 5, Specimens from the most beautiful remains of Grecian architecture. *Figure* 5 is taken from the capitals of that elegant piece of antiquity the Lantern of Demosthenes.

Figures 6, 7, 8, 9, 10, 11, 12, are from the ancient remains of Roman architecture. In particular, *Figure* 9, is taken from the temple of Vesta, at Tivoli; *Figure* 10, from the three remaining columns of the temple of Jupiter Stator, at Rome; *Figure* 12, from the arch of Titus.

ORNAMENTS IN RELIEVO, those carved on the contours of mouldings.

ORTHOGONAL FIGURE (from *ὀρθὸς*, *true*, and *γωνία*, *an angle*) the same as rectangular.

ORTHOGRAPHICAL PROJECTIONS. *See* PROJECTION.

ORTHOGRAPHY (*ὀρθὸς*, *true*, and *γραφω*, *to describe*) in architecture, the elevation of a building, showing all the parts thereof in their true proportion. The orthography is either *external* or *internal.*

ORTHOGRAPHY, *External*, a delineation of the outer face or front of a building, exhibiting the principal wall, with its apertures, roof, ornaments, and everything visible to an eye placed at a distance, before the building.

ORTHOGRAPHY, *Internal*, called also SECTION, a delineation or draught of a building, such as it would appear were the external wall removed. *See* PERSPECTIVE.

ORTHOGRAPHY, in geometry, the art of drawing or delineating the fore-right plan or side of any object, and of expressing the heights or elevations of each part.

This art has received its name from its determining things by perpendicular right lines falling on the geometrical plan; or rather, because all the horizontal lines are here straight and parallel, and not oblique, as in perspective representations.

ORTHOGRAPHY, in fortification, the profile or representation of a work; or a draught so conducted, as that the length, breadth, height, and thickness of the several parts are expressed; such as they would appear, if it were perpendicularly cut from top to bottom.

OSCULATING CIRCLE, or KISSING CIRCLE, the circle of curvature. That circle whose radius is equal to the radius

of curvature of any other curve at a particular or specified point. *See* CURVE.

OVA (from the Latin *ovum*, an egg) an ornament in form of an egg, usually employed in the echinus.

OVAL, a figure in geometry, bounded by a curve line returning to itself.

Under this general definition of an oval is included the ellipsis, which is a mathematical oval; also all other figures which resemble the ellipsis, though with very different properties; and, in short, all curves which return to themselves, go under the name of ovals.

For a description of the mathematical oval, the reader will turn to the article ELLIPSIS, where, it is presumed, he will meet with full satisfaction.

One of the most remarkable properties of the oval kind is the following:

Plate I. *Figure* 1.—Let C E F G be a circle, O its centre; draw any line, E I, through the centre O; then take any point, F, in the circumference. Let F I be an inflexible line, and let M be a given point in the line F I; then, if the point F be conceived to move round the circumference of the circle, while the point, I, the end of this line, F I, moves or slides along the line E I, the point M will describe an oval, almost similar to the conic ellipsis. As we have not seen any equation of this figure, it is presumed that the following investigation, by the author, will be acceptable:

Draw F H perpendicular to the diameter, E G, of the circle, cutting E G at H; also draw M P perpendicular to E I, cutting E I always in P, wherever the point M is situated. Let A be the point in the straight line E I, in which M will coincide when F is brought to E, and B the point where M will coincide when F comes to G.

Then let A P $= x$
P M $= y$
E H $=$
H F $= s$
I M $= a$
I F $= b$
and E G $= d$

From the property of the circle we have $\text{H F}^2 = d\,v - v^2$; then, by similar triangles, I F H and I M P, we have

$$\text{I F}^2 : \text{I M}^2 :: \text{H F}^2 : \text{P M}^2;$$

That is, $b^2 : a^2 :: d\,v - v^2 : y^2 = \frac{a^2}{b^2}(d\,v - v^2)$

Therefore, $y = \frac{a}{b}(d\,v - v^2)^{\frac{1}{2}}$

Then, to find the value of $x = \text{A P}$, we have

$$\text{I P}^2 = \text{I M}^2 - \text{P M}^2 = a^2 - \frac{a^2}{b^2}(d\,v - v^2) = \frac{a^2}{b^2}(b^2 - d\,v + v^2);$$

Therefore, $\text{I P} = \frac{a}{b}(b^2 - d\,v + v^2)^{\frac{1}{2}}$;

But I M : I P :: M F : P H;

That is, $a : \frac{a}{b}(b^2 - d\,v + v^2)^{\frac{1}{2}} :: c : \text{P H} = \frac{c}{b}(b^2 - d\,v + v^2)^{\frac{1}{2}}$

$$\text{I E} = \text{I P} + \text{P H} + \text{H E} = (b^2 - d\,v + v^2)^{\frac{1}{2}} \times \frac{a+c}{b} + v;$$

$$\text{I A} = \text{I E} - \text{A E} = \frac{a+c}{b} \times (b^2 - d\,v + v^2)^{\frac{1}{2}} + v - c;$$

$\text{A P} = \text{I A} - \text{I P} = \frac{c}{b}(b^2 - d\,v + v^2)^{\frac{1}{2}} + v - c$; by which the value of A P, corresponding to P M or $y = \frac{a}{b}(d\,v - v^2)^{\frac{1}{2}}$, may be found in the most simple manner.

Therefore, if A P in the figure were always equal to the versed sine E H of the circle, the curve described by the motion of the point M, would really be an ellipsis; and because P M or $y = \frac{a}{b}(d\,v - v^2)^{\frac{1}{2}}$ it follows, that the axis perpendicular to the ordinates, is to the axis parallel to the ordinates, in the ratio of b to a; that is, in the ratio of I F to I M nearly.

Let $a = 20$, $b = 40$, $c = 20$, and $d = 10$; then will $y = \frac{a}{b}d\,(v - v^2)^{\frac{1}{2}} = \frac{1}{2}(6\,v - v^2)^{\frac{1}{2}}$; from which the following values are obtained, according to the different assumptions of the versed sine, v, of the circle:

Assume $v = 1$, then $\frac{1}{2}(6 \times 1 - 1^2)^{\frac{1}{2}} = \frac{1}{2}(6 - 1)^{\frac{1}{2}} = \frac{5^{\frac{1}{2}}}{2} = 1.118$;

$v = 2$, $\frac{1}{2}(6 \times 2 - 2^2)^{\frac{1}{2}} = \frac{1}{2}(12 - 4)^{\frac{1}{2}} = \frac{8^{\frac{1}{2}}}{2} = 1.4142$;

$v = 3$, $\frac{1}{2}(6 \times 3 - 3^2)^{\frac{1}{2}} = \frac{1}{2}(18 - 9)^{\frac{1}{2}} = \frac{9^{\frac{1}{2}}}{2} = 1.5$;

$v = 4$, $\frac{1}{2}(6 \times 4 - 4^2)^{\frac{1}{2}} = \frac{1}{2}(24 - 16)^{\frac{1}{2}} = \frac{8^{\frac{1}{2}}}{2} = 1.4142$;

$v = 5$, $\frac{1}{2}(6 \times 5 - 5^2)^{\frac{1}{2}} = \frac{1}{2}(30 - 25)^{\frac{1}{2}} = \frac{5^{\frac{1}{2}}}{2} = 1.118$.

Then, because $x = \frac{c}{b}(b^2 - d\,v + v^2)^{\frac{1}{2}} + v - c = \frac{1}{2}(1600 - 6\,v + v^2) + v - 20$, we shall have the following values of x, by the different assumptions of v, which must be those answering to y, as before:

$v = 1$, then $x = \frac{1}{2}(1600 - 6 \times 1 + 1^2)^{\frac{1}{2}} + 1 - 20 = 0.96872$;

$v = 2$, $x = \frac{1}{2}(1600 - 6 \times 2 + 2^2)^{\frac{1}{2}} + 2 - 20 = 1.94993$;

$$v = 3, \text{ then } x = \frac{1}{2}(1600 - 6 \times 3 + 3^2)^{\frac{1}{2}} + 3 - 20 = 2.94367;$$

$$v = 4, \quad x = \frac{1}{2}(1600 - 6 \times 4 + 4^2)^{\frac{1}{2}} + 4 - 20 = 3.94993;$$

$$v = 5, \quad x = \frac{1}{2}(1600 - 6 \times 5 + 5^2)^{\frac{1}{2}} + 5 - 20 = 4.96872;$$

Therefore the abscissas, and the corresponding ordinates of the figure, are as follow:

When $x =$ .96872, then $y = 1.1180$;
$x = 1.94993$, $y = 1.4142$;
$x = 2.94367$, $y = 1.5$;
$x = 3.94993$, $y = 1.4142$;
$x = 4.96872$, $y = 1.1180$.

Figure 2.—Draw the line A B equal to the diameter d, which is 6, from any scale of equal parts, as *Figure* 3, (but the scale to be used ought to be a diagonal one); make A P′ = 0.96872, A P″ = 1.94993, A P‴ = 2.94367, A P^{iv} = 3.94993, A P^{v} = 4.96872; then, having drawn all the lines, P M, cutting A B at right angles, on both sides of A B make P′ M′ = 1.1180, P″ M″ = 1.4142, P‴ M‴ = 1.5, P^{iv} M^{iv} = 1.4142, and P^{v} M^{v} = 1.1180; and through all the points A, P′, P″, P‴, P^{iv}, P^{v}, draw a curve, which will be the oval required.

	Abscissas.	Distances.	Differences.
A P′	= 0.96872	.96871, .98121	.01250
A P″	= 1.94993		.01253
A P‴	= 2.94367	.99374, 1.00626	.01252
A P^{iv}	= 3.94993		.01253
A P^{v}	= 4.96872	1.01879, .98128	.03751
A P^{vi}	= 6.		

So that the last distances, being a little wider than the first, show the figure to be an eggoid.

Another oval, which may be generated in a similar manner, is the following:

Figure 4.—Let C D H F be a circle; let any point, G, be taken in the plane of description; let C be the extremity of an inflexible line; let the point C be carried round the circumference of the circle, while the line always moves through the point G; then will any point, M, taken in this line, describe the oval required.

It is hoped that the reader will be satisfied with this mechanical description, as the investigation of the principle would extend this article to too great a length.

It is now upwards of twenty-five years since the author discovered the two above methods; and a machine for describing the former has been since exhibited for sale in Cornhill, which Mr. J. B. Taylor has applied to the art of engraving with considerable success; and though not mathematically true, it describes a beautiful curve, so very near to an ellipsis, that the defect cannot be detected by the eye. For describing concentric ellipses, or those which have their axes in the same ratio, no method can be so easily applied, as nothing more is required than to adopt the radius to the length of the curve.

A most beautiful figure of an oval may be derived from the equation of a circle of the higher orders; as $y^{m+1} = x^m (a - x)$. The proportion of the figure may be varied at pleasure.

To find the point in the axis through which the ordinate of the greatest breadth passes. As we have the value of $y = (a x^m - x^{m+1})^{\frac{1}{m+1}}$, it is evident that such value has a maximum; therefore, as $a x^m - x^{m+1}$ will have a maximum,

$$m a x^{m-1} x - (m+1) x^m x = o;$$

$$\frac{m a x^m}{x} = (m+1) x^m;$$

$$\frac{m a}{x} = (m+1);$$

$$m a = (m+1) x;$$

$$\text{and } x = \frac{m a}{m+1}.$$

Now let $m = 2$; then will $y = (a x^m - x^{m+1})^{\frac{1}{m+1}}$ become $y = (a x^2 - x^3)^{\frac{1}{3}}$; therefore, to make an oval of this description to any length and breadth, we have in this case $x = \frac{m a}{m+1} = \frac{2 a}{3}$; consequently, the value of the ordinate, when it is a maximum, is $y = \left(\frac{4 a^3}{27}\right)^{\frac{1}{3}} = \frac{a}{3} 4^{\frac{1}{3}}$; hence, to make the length and breadth equal to each other, we have $y = \frac{3}{32^{\frac{1}{3}}}(a x^2 - x^3)^{\frac{1}{3}} = .945 (a x^2 - x^3)^{\frac{1}{3}}$ nearly, three decimal places only being used. Now let p be any proportion, as $\frac{1}{2}$, $\frac{2}{3}$, $\frac{3}{4}$, or any multiple of the semi-axis of the curve; then will $y = .945\, p\, (a x^2 - x^3)^{\frac{1}{3}}$. Let $p = \frac{1}{2}$, and $a = 9$; then $y = .4725\, (9 x^2 - x^3)^{\frac{1}{3}}$.

Now when $x = o$, then will $y = o$; and when $x = a$, then will $y = o$ again; therefore, by assuming x equal to the following values:

$x = 1$, then will $y = .4725\ (9 - 1)^{\frac{1}{3}} = .945$;
$x = 2$, $y = .4725\ (36 - 8)^{\frac{1}{3}} = 1.435$;
$x = 3$, $y = .4725\ (81 - 27)^{\frac{1}{3}} = 1.785$;
$x = 4$, $y = .4725\ (144 - 64)^{\frac{1}{3}} = 2.036$;
$x = 5$, $y = .4725\ (225 - 125)^{\frac{1}{3}} = 2.193$;
$x = 6$, $y = .4725\ (324 - 216)^{\frac{1}{3}} = 2.250$;
$x = 7$, $y = .4725\ (441 - 343)^{\frac{1}{3}} = 2.178$;
$x = 8$, $y = .4725\ (576 - 512)^{\frac{1}{3}} = 1.890$;

Plate II. *Figure* 5. is a curve drawn, according to these abscissas, and ordinates drawn by the diagonal scale, *Figure* 6.

But if, in the following ordinates of the figure,

when $x = 1$, $y = 1.890$
$x = 2$, $y = 2.870$
$x = 3$, $y = 3.570$
$x = 4$, $y = 4.072$
$x = 5$, $y = 4.386$
$x = 6$, $y = 4.5$
$x = 7$, $y = 4.356$
$x = 8$, $y = 3.78$

be respectively multiplied by p, we shall have the axis to the maximum breadth of the figure in any given ratio, according

to the value of p. Thus if $p = \frac{1}{2}$, then the axis of the curve will be to its greatest breadth, parallel to the ordinates, as 2 to 1; for instance,

when $x = 1$, $y = .945$;
$x = 2$, $y = 1.435$;
$x = 3$, $y = 1.785$;
$x = 4$, $y = 2.036$;
$x = 5$, $y = 2.193$;
$x = 6$, $y = 2.25$;
$x = 7$, $y = 2.178$;
$x = 8$, $y = 1.890$;

Again, suppose it were required to make the length of the axis to the greatest breadth, as 3 to 2;

then, when $x = 1$, $y = 1.890 \times \frac{2}{3} = 1.260$;

$x = 2$, $y = 2.870 \times \frac{2}{3} = 1.913$;

$x = 3$, $y = 3.570 \times \frac{2}{3} = 2.380$;

$x = 4$, $y = 4.072 \times \frac{2}{3} = 2.714$;

$x = 5$, $y = 4.386 \times \frac{2}{3} = 2.924$;

$x = 6$, $y = 4.500 \times \frac{2}{3} = 3.$

$x = 7$, $y = 4.356 \times \frac{2}{3} = 2.904$;

$x = 8$, $y = 3.780 \times \frac{2}{3} = 2.580$;

So that, fixing upon the length, divide that length into nine equal parts, and draw lines through the points of division; the length being thus the scale of the work, set off the ordinates on both sides of the axis, according to the value x; that is, each of the first pair of ordinates, 1.26; each of the next pair, 1.913; and so on.

The body of the vase, *Figure* 7, is drawn by this equation.

Another very useful proportion is that in which the greatest double ordinate is three-quarters of the length. From this we shall have the several values of y, as follow:

When $x = 1$, $y = 1.890 \times \frac{3}{4} = 1.417$;

$x = 2$, $y = 2.870 \times \frac{3}{4} = 2.152$;

$x = 3$, $y = 3.570 \times \frac{3}{4} = 2.677$;

$x = 4$, $y = 4.072 \times \frac{3}{4} = 3.054$;

$x = 5$, $y = 4.386 \times \frac{3}{4} = 3.289$;

$x = 6$ $y = 4.500 \times \frac{3}{4} = 3.375$;

$x = 7$, $y = 4.356 \times \frac{3}{4} = 3.267$;

$x = 8$, $y = 3.780 \times \frac{3}{4} = 2.835$;

If the oval be required to have a longer taper, we may use the equation $v = (a x^3 - x^4)^{\frac{1}{4}}$, instead of $y = (a x^3 - x^4)^{\frac{1}{4}}$, which will produce a most beautiful figure; now the property being $y = (a x^3 - x^4)^{\frac{1}{4}}$; let $a = 8$, then $y = (8 x^3 - x^4)^{\frac{1}{4}}$

Let

$x = 1$	then $y = (8$	$- 1)^{\frac{1}{4}}$	$= (7)^{\frac{1}{4}}$	$= 1.626$;
$x = 2$	$y = (8 \times 8$	$- 16)^{\frac{1}{4}}$	$= (48)^{\frac{1}{4}}$	$= 2.632$;
$x = 3$	$y = (8 \times 27$	$- 81)^{\frac{1}{4}}$	$= (135)^{\frac{1}{4}}$	$= 3.408$;
$x = 4$	$y = (8 \times 64$	$- 256)^{\frac{1}{4}}$	$= (256)^{\frac{1}{4}}$	$= 4.000$;
$x = 5$	$y = (8 \times 125$	$- 625)^{\frac{1}{4}}$	$= (375)^{\frac{1}{4}}$	$= 4.400$;
$x = 6$	$y = (8 \times 216$	$- 1296)^{\frac{1}{4}}$	$= (432)^{\frac{1}{4}}$	$= 4.559$;
$x = 7$	$y = (8 \times 343$	$- 2401)^{\frac{1}{4}}$	$= (343)^{\frac{1}{4}}$	$= 4.303.$

These several roots are obtained from two extractions of the square root, as below; the last extraction is only carried to three places of decimals, as being amply sufficient, to construct the figure.

$(7)^{\frac{1}{4}} = (2.6457513)^{\frac{1}{2}} = 1.626$;
$(48)^{\frac{1}{4}} = (6.9282032)^{\frac{1}{2}} = 2.632$;
$(135)^{\frac{1}{4}} = (11.6189500)^{\frac{1}{2}} = 3.408$;
$(256)^{\frac{1}{4}} = (16.0000000)^{\frac{1}{2}} = 4.000$;
$(375)^{\frac{1}{4}} = (19.3649167)^{\frac{1}{2}} = 4.400$;
$(432)^{\frac{1}{4}} = (20.7846097)^{\frac{1}{2}} = 4.559$;
$(343)^{\frac{1}{4}} = (18.5202592)^{\frac{1}{2}} = 4.303.$

Since $x = \frac{m\,a}{m+1}$ in every description of an oval; therefore, in this particular curve, where m is equal to 3, we shall have $x = \frac{3\,a}{4}$; that is, the greater double ordinate will pass through a point in the axis, distant from the extremity where the abscissa begins three-quarters of the length of the axis.

But in order to accommodate this equation to every length and breadth, it will be eligible in the first place to calculate the ordinates, so as to make the greatest double ordinate equal to the length of the axis, as in the preceding equation. The value of the greatest ordinate will therefore be $y = (a x^3 - x^4)^{\frac{1}{4}} = \left(\frac{27\,a^4}{64} - \frac{81\,a^4}{256}\right)^{\frac{1}{4}} = \left(\frac{27\,a^4}{256}\right)^{\frac{1}{4}} = \frac{a}{4} \times 27^{\frac{1}{4}}$

$= \frac{27^{\frac{1}{4}}\,a}{4}$; hence $\frac{27^{\frac{1}{4}}\,a}{4} : \frac{a}{2} :: (a x^3 - x^4)^{\frac{1}{4}} : \frac{2}{27^{\frac{1}{4}}}(a x^3 - x^4)^{\frac{1}{4}}$.

So that $y = \frac{2}{27}(a x^3 - x^4)^{\frac{1}{4}}$ when the greatest double ordinate is equal in length to the axis; and if r be the ratio which the axis has to the greatest double ordinate, $y = \frac{2\,r}{27^{\frac{1}{4}}}(a x^3 - x^4)^{\frac{1}{4}} = .877\ r\ (a x^3 - x^4)^{\frac{1}{4}}$.

If the several values of y, as before calculated, be multiplied by .877, we shall obtain the following:

When $x = 1$, $y = 1.626 \times .878 = 1.427$;
$x = 2$, $y = 2.632 \times .878 = 2.311$;
$x = 3$, $y = 3.408 \times .878 = 2.999$;
$x = 4$, $y = 4.000 \times .878 = 3.511$;
$x = 5$, $y = 4.400 \times .878 = 3.866$;
$x = 6$, $y = 4.559 \times .878 = 4.$;
$x = 7$, $y = 4.303 \times .878 = 3.778$;

Each of these values being multiplied by r, will give the proportion of the figure required.

Now let $r = \frac{1}{3}$;

Figure 8 is drawn by these numbers; the vase, *Figure* 9, and the jug, *Figure* 10, are drawn by the same equation, by varying the numbers.

then when $x = 1$, $y = 1.427\ r = .475$
$x = 2$, $y = 2.31\ r = .77$
$x = 3$, $y = 2.99\ r = .996$
$x = 4$, $y = 3.51\ r = 1.17$
$x = 5$, $y = 3.86\ r = 1.286$
$x = 6$, $y = 4.\ r = 1.333$
$x = 7$, $y = 3.778\ r = 1.259$

Again, let $r = \frac{1}{2}$;
then when $x = 1$, $y = 1.427\ r = .713$;
$x = 2$, $y = 2.31\ r = 1.155$;
$x = 3$, $y = 2.99\ r = 1.495$;
$x = 4$, $y = 3.51\ r = 1.755$;
$x = 5$, $y = 3.86\ r = 1.93$;
$x = 6$, $y = 4.\ r = 2.$
$x = 7$, $y = 3.778\ r = 1.889.$

Let $r = \frac{2}{3}$;
then when $x = 1$, $y = 1.427\ r = .951$;
$x = 2$, $y = 2.31\ r = 1.54$;
$x = 3$, $y = 2.99\ r = 1.99$;
$x = 4$, $y = 3.51\ r = 2.34$;
$x = 5$, $y = 3.86\ r = 2.57$;
$x = 6$, $y = 4.\ r = 2.66$;
$x = 7$, $y = 3.778\ r = 2.518.$

And, lastly, let $r = \frac{3}{4}$;
then when $x = 1$, $y = 1.427\ r = 1.07$;
$x = 2$, $y = 2.31\ r = 1.73$;
$x = 3$, $y = 2.99\ r = 2.24$;
$x = 4$, $y = 3.51\ r = 2.63$;
$x = 5$, $y = 3.86\ r = 2.89$;
$x = 6$, $y = 4.\ r = 3$;
$x = 7$, $y = 3.778\ r = 2.833.$

Another equation, which gives the oviform figure more swell at the quicker end, is the following: $y = (a^2 x^2 - x^4)^{\frac{1}{4}}$. Let

$x = 1$ then $y = (100 - 1)^{\frac{1}{4}} = 99^{\frac{1}{4}} = 3.15$;
$x = 2$ $y = (400 - 16)^{\frac{1}{4}} = 384^{\frac{1}{4}} = 4.42$;
$x = 3$ $y = (900 - 81)^{\frac{1}{4}} = 819^{\frac{1}{4}} = 5.31$;
$x = 4$ $y = (1600 - 256)^{\frac{1}{4}} = 1344^{\frac{1}{4}} = 6.05$;
$x = 5$ $y = (2500 - 625)^{\frac{1}{4}} = 1875^{\frac{1}{4}} = 6.58$;
$x = 6$ $y = (3600 - 1296)^{\frac{1}{4}} = 2304^{\frac{1}{4}} = 6.92$;
$x = 7$ $y = (4900 - 2401)^{\frac{1}{4}} = 2499^{\frac{1}{4}} = 7.07$;
$x = 8$ $y = (6400 - 4096)^{\frac{1}{4}} = 2304^{\frac{1}{4}} = 6.92$;
$x = 9$ $y = (8100 - 6561) = 1539^{\frac{1}{4}} = 6.26.$

Calling the abscissal axis the height, the construction may be accommodated to any given dimensions, as follows; for this purpose we have the fluxion of $a^2 x^2 - x^4 = 0$; therefore $4 x^3 x = 2 a^2 x$; consequently $x^2 = \frac{a^2}{2}$; and hence $x = \frac{a}{2^{\frac{1}{2}}}$ will give the point through which the greatest double ordinate passes. If therefore this quantity be substituted for x in the equation $y = (a^2 x^2 - x^4)^{\frac{1}{4}}$, then will $y = \left(\frac{a^4}{2} - \frac{a^4}{4}\right)^{\frac{1}{4}} = \left(\frac{2\,a^4}{4} - \frac{a^4}{4}\right)^{\frac{1}{4}} = \left(\frac{a^4}{4}\right)^{\frac{1}{4}} \frac{a}{2^{\frac{1}{4}}} =$; therefore $\frac{a}{2^{\frac{1}{4}}} : \frac{a}{4} :: (a^2 x^2 - x^4)^{\frac{1}{4}} : \frac{1}{2^{\frac{1}{4}}}(a^2 x^2 - x^4)^{\frac{1}{4}} = 7071\ (a^2 x^2 - x^4)^{\frac{1}{4}}$; so that, taking $x = \frac{a}{2^{\frac{1}{4}}}$, we shall have $y = \frac{a}{2}$, as it ought to be. Therefore, if the ratio be r, we shall have $.7071\ r\ (a^2 x^2 - x^4)^{\frac{1}{4}}$, for any proportion according to the nominal value of r. Now let $r = \frac{2}{3}$, then a being 10, as before, we shall have the several values of y as follow:

when $x = 1$, then $y = 2.23$;
$x = 2$ $y = 3.13$;
$x = 3$ $y = 3.75$:
$x = 4$ $y = 4.28$;
$x = 5$ $y = 4.65$;
$x = 6$ $y = 4.89$;
$x = 7$ $y = 5.00$;
$x = 8$ $y = 4.89$;
$x = 9$ $y = 4.43.$

If the equation of the curve be $y = (c^3 - x^3)^{\frac{1}{3}}$, the following values of y will be found, supposing $c = 5$;

when $x = 0$, $y = (125 - 0)^{\frac{1}{3}} = 5.$;
$x = 1$, $y = (125 - 1)^{\frac{1}{3}} = 4.986$;
$x = 2$, $y = (125 - 8)^{\frac{1}{3}} = 4.89$;
$x = 3$, $y = (125 - 27)^{\frac{1}{3}} = 4.610$;
$x = 4$, $y = (125 - 64)^{\frac{1}{3}} = 3.936$;
$x = 5$, $y = (125 - 125)^{\frac{1}{3}} = 0.$

Figure 11, is drawn by these numbers, according to the diagonal scale, *Figure* 13.

Figure 12, is drawn by the same equation, to a different set of numbers, to the same scale, *Figure* 13.

Another equation, by which figures of this description may be obtained, is the following:

$y = (a x - x^2)^{\frac{1}{4}}$. Let $a = 10$,
$x = 1$, $y = (10 - 1)^{\frac{1}{4}} = 1.73$;
$x = 2$, $y = (20 - 4)^{\frac{1}{4}} = 2.$;
$x = 3$, $y = (30 - 9)^{\frac{1}{4}} = 2.14$;
$x = 4$, $y = (40 - 16)^{\frac{1}{4}} = 2.21$;
$x = 5$, $y = (50 - 25)^{\frac{1}{4}} = 2.23.$

But perhaps the most beautiful figure of the oval species is the ellipsis. The equation of the circle is $y = (d x - x^2)^{\frac{1}{2}}$; let $d = 20$, then will $y = (20 x - x^2)^{\frac{1}{2}}$; then when

$x = 1$, $y = (20 - 1)^{\frac{1}{2}} = 19^{\frac{1}{2}} = 4.3588989$;
$x = 2$, $y = (40 - 4)^{\frac{1}{2}} = 36^{\frac{1}{2}} = 6.$
$x = 3$, $y = (60 - 9)^{\frac{1}{2}} = 51^{\frac{1}{2}} = 7.1414284$;
$x = 4$, $y = (80 - 16)^{\frac{1}{2}} = 64^{\frac{1}{2}} = 8.$
$x = 5$, $y = (100 - 25)^{\frac{1}{2}} = 75^{\frac{1}{2}} = 8.660254$;
$x = 6$, $y = (120 - 36)^{\frac{1}{2}} = 84^{\frac{1}{2}} = 9.1651514$;
$x = 7$, $y = (140 - 49)^{\frac{1}{2}} = 91^{\frac{1}{2}} = 9.539392$;
$x = 8$, $y = (160 - 64)^{\frac{1}{2}} = 96^{\frac{1}{2}} = 9.797959$;
$x = 9$, $y = (180 - 81)^{\frac{1}{2}} = 99^{\frac{1}{2}} = 9.9493744$;
$x = 10$, $y = (200 - 100)^{\frac{1}{2}} = 100^{\frac{1}{2}} = 10.$

From these numbers, ellipses may be constructed, of any length and breadth, by multiplying them by the ratio of the axis $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, $\frac{1}{3}$, $\frac{2}{3}$, supposing the breadth to be $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, $\frac{1}{3}$, $\frac{2}{3}$ of the length.

A kind of oval, as it is called, which may easily be described through points, is the following:

Figure 14, No. 1, describe a semicircle, A P C, on the diameter A C, for the length: draw A D perpendicular and equal to A C; take any point, B, in A C; join B D; draw B *p* parallel to A D, cutting the circle in *p*; draw *p m* perpendicular to B *p*, cutting B D at *m*; make A C, No. 2, equal to A C, No. 1; and every A P in No. 2, equal to every A B in No. 1; also every P M in No. 2, equal to the corresponding *p m* in No. 1: through all the points, M, draw a curve.

This figure is of the form of *a pear*, and not what may be denominated *an oval*.

OVICULUM, in ancient architecture, a little ovum, or egg.

OVOLO, (from the Latin *ovum*, an egg) a convex moulding, of which the lower extremity recedes from a perpendicular or vertical line drawn from the upper. *See* MOULDINGS.

OUNCE, a small weight, the sixteenth part of a pound avoirdupois, and the twelfth part of a pound Troy.

OUTER DOORS, those which are common to both the exterior and interior sides of a building, made to prevent entrance at the pleasure of the occupier.

OUTFALL, or OUTLET, the exit or termination of a drain, &c., where it discharges its contents.

OUTLINE, the contour or boundary of an object.

OUT OF WINDING, a term used by artificers to signify that the surface of a body is that of a plane; or, when two straight edges are in the same plane, they are said to be out of winding.

OUT-TO-OUT, an expression used when a dimension is taken to the utmost bounds of a body or figure.

OUTWARD ANGLE, the same as salient angle.

OXYGON, (Greek, *ὀξος*, *sharp*, and *γωνία*, *an angle*), an acute-angled triangle.

P.

PAG

PACE, two and a half feet. The geometrical pace is five feet, and 60,000 such paces make one degree of the equator.

PACE, a raised platform, such as the dais at the upper end of the old halls, &c.

PADDLE, (from the Welsh, *pattal*) a small sluice, similar to those by which locks are filled or emptied.

PADDLE HOLES, the crooked arches through which the water passes from the upper pond of a canal into the lock, to fill it; or through which it is let out into the lower pond, on the entrance and exit of vessels. They are sometimes called CLOUGH ARCHES.

PADDLE WEIRS. *See* LOCK WEIRS.

PADDOCK, or PADDOCK COURSE (from the Saxon *pado*, or Dutch *padde*) a piece of ground generally taken out of a park, ordinarily a mile long, and a quarter of a mile broad, encompassed with pales or a wall, for the exhibiting of races with greyhounds, for wagers, plates, or the like.

At one end of the paddock was a little house, where the dogs were to be entered, and whence they were slipped; near which were pens to enclose two or three deer for the sport.

The deer, when turned loose, ran along by the pale; and the spectators were placed on the other side.

Along the course were several posts; viz., the lawpost, 160 yards from the dog-house and pens; the-quarter-of-a-mile post; half-mile post; and pinching post; beside the ditch, a place made to receive the deer, and preserve them from farther pursuit. Near the ditch were the judges, or triers.

PÆSTUM, a town of Italy, about sixty miles distant from Naples, remarkable for the remains of a large and very beautiful temple, dedicated to Neptune, and of the Doric order. Remains of other temples, an amphitheatre and the city wall, are also to be seen here.

PAGOD, or PAGODA, a name probably Indian, which the Portuguese have given to all the temples of the Indians, and all the idolaters of the East.

These pagods, or pagodas, are mostly square; they are stone buildings, which are not very lofty, and are crowned with a cupola. Within they are very dark; for they have no windows, and only receive their light through the entrance. The image of the idol stands in the deepest and darkest recess of the temple; it is of a monstrous shape, and of uncouth dimensions, having many arms and hands. Some of these idols have eight, and others sixteen arms; with a human body, and the head of a dog, with drawn bows and

PAG

instruments of war in their hands. Some of them are black, others of a yellowish hue. In some pagodas there are no images, but only a single black polished stone, lying upon a round altar, covered with flowers and sandal-wood, which were strewed upon it. Greater veneration is manifested for these stones than for the idols themselves. Their worship of these divinities consists in throwing themselves upon the ground, and making their salam, or salutation, with their hands, and ejaculating their prayers in silence, in that posture. The offerings which they are accustomed to present to their gods, consist of flowers, rice, pieces of silk and cotton, and sometimes gold and silver. Everything is laid before the idols, and is taken care of by the Bramins, who profit the most by it. They guard the pagodas both by day and night. The pagodas of China are lofty towers, which sometimes rise to the height of nine stories, of more than 20 feet each. *See* CHINESE ARCHITECTURE.

In order to give such an idea of these buildings as may enable the reader to judge with respect to the early state of the arts in India, we shall briefly describe two, of which we have the most accurate accounts. The entry to the pagoda of Chillambrum, near Porto Novo, on the Coromandel coast, held in high veneration on account of its antiquity, is by a stately gate under a pyramid, 122 feet in height, built with large stones above forty feet long, and more than five feet square, and all covered with plates of copper, adorned with an immense variety of figures, neatly executed. The whole structure extends 1332 feet in one direction, and 936 in another. Some of the ornamental parts are finished with an elegance entitled to the admiration of the most ingenious artists. The pagoda of Seringham, superior in sanctity to that of Chillambrum, surpasses it as much in grandeur; and, fortunately, we can convey a more perfect idea of it by adopting the words of an elegant and accurate historian. This pagoda is situated about a mile from the western extremity of the island of Seringham, formed by the division of the great river Caveri, into two channels. "It is composed of seven square enclosures, one within the other, the walls of which are 25 feet high, and four thick. These enclosures are 350 feet distant from one another, and each has four large gates with a high tower; which are placed, one in the middle of each side of the enclosure, and opposite to the four cardinal points. The outward wall is near four miles in circumference, and its gateway to the south is ornamented with pillars, several of which are single stones, 33 feet long, and nearly five in diameter. and those which

form the roof are still larger; in the inmost inclosures are the chapels. About half a mile to the east of Seringham, and nearer to the Caveri than the Coleroon, is another large pagoda, called Jembikisma; but this has only one inclosure. The extreme veneration in which Seringham is held, arises from a belief that it contains that identical image of the god Wistchnu, which used to be worshipped by the god Brahma. Pilgrims from all parts of the Peninsula come here to obtain absolution, and none come without an offering of money; and a large part of the revenue of the island is allotted for the maintenance of the Brahmins who inhabit the pagoda; and these, with their families, formerly composed a multitude not less than forty thousand souls maintained without labour, by the liberality of superstition. Here, as in all the other great pagodas of India, the Brahmins live in a subordination which knows no resistance, and slumber in a voluptuousness which knows no wants."

The pagodas of the Chinese and Siamese are exceedingly magnificent. *See* INDIAN ARCHITECTURE.

PAINTERS, *House*. Painter's work is measured by the square yard in the same manner as wainscoting, the mouldings being measured by a thread. The sashes of windows are paid for by the piece; and it is usual to allow double measure for carved mouldings, &c.

PAINTING, the art of imitating the appearances of natural objects, by means of artificial colours spread over a surface; the colouring substances being used either dry, as in crayon painting; or compounded with some fluid vehicle, as oil, water, or solutions of different gums and resins in oil or spirits, &c.

The theory and practice of this ingenious art are divided by its professors into five principal parts; viz., *invention*, or the power of conceiving the materials proper to be introduced into a picture; *composition*, that of arranging those materials; *design*, that of delineating them; *chiaro-scuro*, or the arrangement and management of the lights and shades, and of light and dark colours; and *colouring*, whose name sufficiently designates its end.

PAINTING, *Economical*, that application of artificial colours, compounded either with oils or water, which is employed in preserving or embellishing houses, ships, furniture, &c. &c. The term economical, applies more immediately to the power which oil and varnishes possess, of preventing the action of the atmosphere upon wood, iron, and stucco, by interposing an artificial surface; but it is here intended to use the term more generally; in allusion to the decorative part, as applied to buildings; as well as to its more essential ones; and as it is employed by the architect, throughout every part of his work, both externally and internally.

In every branch of painting in oil, as applicable either to churches, theatres, houses, or any other public or private buildings, or edifices, the general process will be found very similar; or with such variations, as will easily be suggested by the judicious artist or workman.

The first coatings, or layers, if on wood or iron, ought always to be of ceruse or white lead, the very best that can be obtained; which should have been previously ground very fine in nut or linseed oil, either over a stove with a muller, or, as that mode is too tedious for large quantities, it may be passed through a mill. If used on wood, as shutters, doors, or wainscoting made of fir or deal, it is highly requisite to destroy the effects of the knots; which are generally so completely saturated with turpentine, as to render it, perhaps, one of the most difficult processes in the business to conquer. The best mode in common cases, is to pass over the knots with ceruse ground in water; bound by a size made of parchment, or some other animal substance. When that is dry, paint the knots with white lead ground in oil, to which add some powerful siccative, or dryer; as red lead, or litharge of lead, about one-fourth part of the latter. These preparations should be done carefully, and laid very smoothly with the grain of the wood. When the last coat is dry, which will be in twelve or twenty-four hours, then smooth it with pumice-stone, or give the work the first coat of paint, prepared, or diluted with nut or linseed oil. When that is dry, all the nail-holes or other irregularities on the surface should be carefully stopped with a composition of oil and Spanish white, a whiting commonly known by the name of putty: but which is frequently made and sold in the shops of very inferior articles. When that is done, let the work be painted over again, with the same mixture of white lead and oil, somewhat diluted with the essence of oil of turpentine, which process should be repeated not less than three or four times, if the work is intended to be left, when finished, of a plain white or stone colour; if of the latter, the last coat should have a small quantity of ivory or lamp-black added to reduce its whiteness a little; and this is also of service in preserving the colour from changing: a circumstance which the oil is apt to produce. But if the work is to be finished of any other colour, either gray, green, &c., it will be requisite to provide for such colour, after the third operation, particularly if it is to be finished flat, or as the painters style it, dead white, gray, fawn, &c. In order to finish the work flatted or dead, (which is a mode much to be preferred for all superior works; not only for its appearance, but also for preserving the colour and purity of the tint) after the work, supposing it to be wood, has been painted four times in oil-colour, as directed in general cases, one coat of the flatted colour, or colour mixed up with a considerable quantity of turpentine, will be found sufficient; although in large surfaces it will frequently be requisite to give two coats of the flatting colour to make it quite complete. Indeed, on stucco it will be almost a general rule; but as that will be hereafter treated on, we shall at present say no more concerning it.

It must be observed, that in all the foregoing operations, it will be requisite to add some sort of siccative. A very general and useful one is made by grinding in linseed, or, perhaps, prepared oils, boiled, are better, about two parts of the best white copperas, which must be well dried, with one part of litharge of lead; the quantity to be added will much depend on the dryness or humidity of the atmosphere at the time of painting, as well as the local situation of the building.

It is highly proper here to observe, that there is a kind of copperas made in England, and said to be used for some purposes in medicine, that not only does not assist the operation of drying-in the colours, but absolutely prevents those colours drying, which would otherwise have done so by themselves. The best dryer for all fine whites, and other delicate tints, is saccharum saturni, or sugar of lead, ground in nut-oil; but which being very active, a small quantity, about the size of a walnut, will be sufficient for twenty pounds of colour, where the basis is ceruse. It will be always worthy to be observed, that the greatest care should be taken to keep all the utensils, brushes, &c., particularly clean, or the colours will soon become very foul, so as to destroy the surface of the work. If this should so happen, the colour should be passed through a fine sieve, or canvass; and the surface of the work be carefully rubbed down with sand-paper, or pumice-stone; and the latter should be prepared by being ground in water, if the paint be tender, or recently laid on.

The above may suffice as to painting on wood, either on outside or inside works; the former being seldom finished

otherwise than in oil, four or five coats are generally quite sufficient.

We shall now proceed to note what is requisite for the painting of new walls, or stucco, not painted before and prepared for oil-colours.

It does not appear that any painting in oil can be done to any good or serviceable effect in stucco, unless not merely the surface appear dry, but that the walls have been erected a sufficient time to permit the mass of brick-work to have acquired a sufficient degree of dryness: when stucco is on battened work, it may be painted over much sooner than when prepared as brick. Indeed, the greatest part of the mystery of painting stucco, so as to stand or wear well, certainly consists in attending to these observations; for whoever has observed the expansive power of water, not only in congelation, but also in evaporation, must be well aware that when it meets with any foreign body obstructing its escape, as oil-paintings for instance, it immediately resists it; forming a number of vesicles, or particles, containing an acrid lime-water, which forces off the layers of plaster, and frequently causes large defective patches extremely difficult to get the better of.

Perhaps, in general cases, where persons are building on their own estates, or for themselves, two or three years are not too long to suffer the stucco to remain unpainted; though frequently, in speculative works, as many weeks are scarcely allowed. Indeed, there are some nostrums set forth in favour of which it is stated, in spite of all the natural properties of bodies, that stucco may, after having been washed over with these liquids, be painted immediately with oil-colours. It is true there may be instances, and in many experiments some will be found, that appear to counteract the general laws of nature; but, on following them up to their causes it will be found otherwise.

Supposing the foregoing precautions to have been attended to, there can be no better mode adopted for priming or laying on the first coat on stucco, than by linseed or nut-oil, boiled with dyers, as before mentioned, with a proper brush; taking care, in all cases, not to lay on too much, so as to render the surface rough and irregular, and not more than the stucco will absorb. It should then be covered with three or four coats of ceruse, or white lead, prepared as described for painting on wainscoting; letting each coat have sufficient time to dry hard. If time will permit, two or three days between each layer will not be too long.

If the stucco be intended to be finished of any given tint, as gray, light green, apricot, &c., it will then be proper, about the third coat of painting, to prepare the ground for such tint by a slight advance towards it.

Gray is made with ceruse, Prussian blue, ivory black, and lake; sage green, pea, and sea greens, with white, Prussian blue, and fine yellows; apricot and peach, with lake, white, and Chinese vermilion; fine yellow fawn colour, with burnt terra Sienna, or umber, and white; olive greens, with fine Prussian blue and Oxfordshire ochre.

Painting in distemper, or water-colours mixed with size, stucco, or plaster, which is intended to be painted in oil when finished, but not being sufficiently dry to receive the oil, may have a coating in water-colours, of any given tint required, in order to give a more finished appearance to that part of the building. *See* DISTEMPER FRESCO.

Straw colours may be made with French white, ceruse, and masticot, or Dutch pink. Grays, fine, with some whites, and refiners' verditer. An inferior gray may be made with blue-black, or bone-black, and indigo. Pea-greens, with French green, Olympian green, &c. Fawn colour with burnt terra de Sienna, or burnt umber and white: and so of any intermediate tint. The colours should all be ground very fine, and incorporated with white, and a size made of parchment, or some similar substance; isinglass being too expensive for common works.

It will not require less than two coats of any of the foregoing colours in order to cover the plaster, and bear out with a uniform appearance. It must be recollected, that when the stucco is sufficiently dry, and it is desirable to have it painted in oil, the whole of the water-colour ought to be removed; which may be easily done by washing; and when quite dry, proceed with it after the directions given in oil-painting of stucco.

When old plastering has become discoloured by stains, and it is desired to have it painted in distemper; it is then advisable to give the old plaster, when properly cleaned off and prepared, one coat at least of white lead ground in oil, and used with spirits of turpentine, which will generally fix all old stains; and when quite dry, will take the water-colours very kindly.

The above processes will also apply to old wainscoting, in cases where temporary painting is only required; but cannot be recommended for durability.

PADDLE WEIRS, see LOCK WEIRS.

PALACE, (from the Latin *palatium*), a word implying, in its stricter sense, a royal abode, but occasionally applied to the residences of other persons; the accompanying epithet indicating the quality of the inhabitants, as imperial palace, ducal palace, &c. In Italy the term Palazzo, taken by itself, is used for any large mansion or nobleman's house; and palaces of this class constitute, after churches, the principal architectural features of Genoa, Florence, Rome, Milan, Vicenza, Venice, and other cities, to which they impart an air of grandeur which is wanting in the street architecture of this country; for in spite of all other defects, and the bad taste they frequently display, they generally possess the redeeming quality of dignity. Our own metropolis, on the contrary, possesses scarcely half a dozen private mansions that have any pretensions to external nobleness of style. In fact, the most palazzo-like buildings we have are our modern club-houses. Neither are any of our royal palaces, with the single exception of Windsor, stamped with architectural magnificence; both in extent and style they are surpassed by several of the country seats of our nobility. Throughout the whole of Europe very few royal palaces, whatever may be their magnitude, are at all distinguished by superior architectural taste. In the French capital it is only the eastern façade of the Louvre, the river-front, and the inner-court, which can lay claim to beauty or richness, the Tuileries being only a mass of quaint grotesqueness. The Vatican at Rome is merely a huge irregular pile; and Versailles and the Escurial, notwithstanding the millions they cost, are both monuments of exceedingly bad taste. Though far from beautiful, the royal palace at Madrid, begun in 1737, from the designs of Giambattista Sachetti, an Italian architect, is a stately and regular pile, it being 470 feet square, and 100 in height, but the effect such a mass would otherwise produce is greatly impaired by the number of mezzanines. The same remark applies to the celebrated palace erected by the king of Naples, about the middle of the last century, at Caserta, and of which Vanvitelli was the architect. This building is certainly characterized by magnitude, for it extends 731 feet from east to west, and 569 from north to south; yet of either grandeur of conception, or majesty of style, there is very little, certainly not enough, to reconcile us to the prodigal execution of so very indifferent a design. The royal palace at Stockholm is a stately edifice in the Italian style, although the original design, by Count Tessin, was considerably curtailed. The

original imperial winter palace at St. Petersburgh was a vast pile erected by the Italian architect Rastrelli, in the reign of the empress Elizabeth, of most imposing aspect towards the quay of the Neva, but exceedingly heavy and grotesque as to style.

Enormous as have been the sums expended upon many of these edifices, every one of them falls very short of the ideal of a royal palace, in which, if anywhere, not only all the luxury and pomp of architecture, but a certain colossal dignity of aspect, should present itself. This can never be accomplished where stories above stories are allowed to display themselves externally. That is but a vulgar species of architectural grandeur which is produced by a numerical multiplication of little parts and features. All the rooms required for the accomodation of an extensive household should be turned towards inner courts, and the whole exterior, having only a single range of lofty windows above the ground-floor, should be left for the unrestrained display of architecture, and sculpture upon a noble scale, without any intermixture of littlenesses. By such a disposition, too, convenience would perhaps be found far better consulted than at present, because, while all the apartments for official and state receptions and court entertainments could be connected together, the whole of the vast number of subordinate rooms required in such a habitation would be concentrated within the general plan, and at the same time might be kept entirely apart, by means of galleries between the outer and inner range, communicating at intervals with lesser vestibules and staircases attached to the suites of lesser rooms and private apartments of every description.

PALÆSTRA, or Palestra, (from the Greek παλαιϛρα) among the ancient Greeks, a public building, where the youth exercised themselves in wrestling, running, playing at quoits, &c.

Some say the palestræ consisted of a college and an academy; the one for exercises of the mind, the other for those of the body. But most authors rather take the palestra to be a xystus, or mere academy for bodily exercises, according to the etymology of the word, which comes from παλη, *wrestling*, one of the chief exercises among the ancients.

The length of the palæstra was marked out by stadia, each equal to 125 geometrical paces; and hence the name *stadium* was given to the arena whereon they ran.

PALATINE BRIDGE, a bridge of ancient Rome, now called St. Mary's bridge, which crosses over from the present church of St. Mary the Egyptian, at the lower end of the Forum Boarium to the Via Transtiberina. This bridge is supposed to be that which Livy speaks of (*Decad.* 4. lib. 10.) built by M. Fulvius, washed down by the Tiber, and afterwards rebuilt by the censors Scipio Africanus and L. Mummius. Another indundation having damaged it, Pope Gregory XIII. repaired it, partly upon the old piles, in the year 1575. But another inundation sweeping away some of it in 1598, it has never since been repaired, so as to be serviceable.

PALE, (from the Latin *palus*) a little pointed stake, or piece of wood, used in making enclosures, separations, &c.

PALES, or Piles, in carpentry, rows of stakes driven deep in the ground to make wooden bridges over rivers, and to erect other edifices on.

Du-Cange derives the word from the Latin name *palla*, *a hanging* or *piece of tapestry*: the ancients gave the name *pales* to the hangings or linings of walls: thus a chamber was said to be *paled* with cloth of gold, with silk, &c., when covered with bands or stuffs of two colours. Hence also the original of the word pale, *a stake*, &c.

Tertullian observes, that the Romans planted pales to serve as boundaries of inheritances; and that they consecrated them to the god Terminus, under the name of *Pali Terminales*.

Ovid tells us, they were crowned and adorned with flowers, festoons, &c., and that the god was worshipped before these pales. *See* Terminalia.

Pales for building, serve to support the beams which are laid across them, from one row to another; and are strongly bound together with cross pieces. *See* Piles.

PALETTE (French) among painters, a little oval table, or piece of wood, or ivory, very thin and smooth; on and round which the painters place the several colours they have occasion for, to be ready for the pencil.

The middle serves to mix the colours on, and to make the teints required in the work. It has no handle, but a hole at one end, to put the thumb through to hold it.

PALING, in agriculture, a kind of fence-work for fruit-trees, &c., planted in exposed places.

It consists of three small posts driven into the ground, at a foot and half distance, with cross bars nailed to each other, near the top.

In fixing the pales in form of a triangle, room is to be left for the tree to play and bow by the high winds, without galling. The trees are to be bound to a stake for a year or two; after which fern or straw may be stuffed in between the tree and uppermost rails, to keep it upright.

If the place be open to deer, rabbits, or the like, a post is to be nailed to the bar between every two pales.

Paling Fence, that sort of fence which is constructed with pales.

PALISADE (French) or Palisado (Italian) in fortification, an enclosure of stakes or piles driven into the ground, each six or seven inches square, and nine or ten feet long: three of which are hid under ground. They are fixed about six inches asunder, and braced together by pieces nailed across them near the tops, and secured by thick posts at the distance of every four or five yards.

Palisades are placed in the covert-way, at three feet from, and parallel to, the parapet or ridge of the glacis, to secure it from being surprised. They are also used to fortify the avenues of open forts, gorges, half-moons, the bottoms of ditches, the parapets or covered ways; and, in general, all posts liable to surprise, and to which the access is easy.

Palisades are usually planted perpendicularly; though some make an angle inclining towards the ground next the enemy, that the ropes cast over them, to tear them up, may slip.

Palisades, *Turning*, are an invention of M. Coehorn, in order to preserve the palisades of the parapet of the covert-way from the besiegers' shot.

These palisades are so arranged that as many of them as stand in the length of a rod, or in about ten feet, turn up and down like traps; so as not to be in sight of the enemy till they just bring on their attack; and yet are always ready to do the proper service of palisades.

PALLADIAN ARCHITECTURE. A style of Italian Architecture introduced by Palladio, for an account of which see Italian Architecture, and the following article.

PALLADIO, ANDREA, in biography, a celebrated Italian architect, born at Vicenza in 1518. He obtained instructions from the poet Trissino, who discovering in him a genius for sculpture and the arts connected with it, taught him the elements of the mathematics, and explained to him the works of Vitruvius. He soon obtained distinction as an architect, and having an opportunity of accompanying his patron to Rome, he employed all his faculties in examining

the remains of ancient edifices in that capital, and formed his taste upon them. On his return, many works of importance were committed to him, which he managed with great skill, and obtained for himself a high reputation. He was now sent for to Venice, where he built the palace Foscari in the style of pure antiquity. Several other Italian cities were afterwards decorated with magnificent edifices, public and private, of his construction, and he was invited to the court of Emanuel Philibert, Duke of Savoy, who received him with distinguished honours. To Palladio is chiefly attributed the classic taste which reigns in so many of the buildings of Italy. His master-piece is reckoned the Olympic theatre at Vicenza, in imitation of that of Marcellus at Rome. He died in that city in 1580, having greatly improved the art, not only by his edifices, but by his writings, which are standard performances. Of these the following account is given: his *Treatise on Architecture,* in four books, was first published at Venice in 1570, folio, and has several times been reprinted. A magnificent edition, in three volumes, folio, was published at London in 1715, in Italian, French, and English. Another, equally splendid, has since been published at Venice, in four volumes, folio, with the addition of his inedited buildings. Lord Burlington published in London, in 1730, a volume entitled, *Idisegni delle Terme Antiche di Andrea Palladio.* He composed a small work, intitled *Le Antichità di Roma*, not printed till after his death. He illustrated Cæsar's *Commentaries*, by annexing to Badelli's translation of that work, a preface on the military system of the Romans, with copper-plates, designed, for the most part, by his two sons, Leonida and Orazio, who both died soon after. Palladio was modest in regard to his own merit, but he was a friend to all men of talents; his memory is highly honoured by the votaries of the fine arts; and the simplicity and purity of his taste have given him the appellation of the Raphaël of architects.

PALLADIUM (from the Greek Παλλας, *the goddess of war*) in antiquity, a statue of the goddess Pallas, or Minerva, three cubits high, holding a pike in the right hand, and a distaff and spindle in the left, preserved in Troy, in the temple of Minerva, on which the fate of that city is said to have depended.

The tradition is, that in building a citadel, in honour of Pallas, and a temple in the most elevated part of it, the palladium dropped from heaven, and marked out the place which the goddess was pleased to possess. After this, Apollo gave an oracle, importing that Troy should never be taken while the palladium was found within its walls: which occasioned Diomedes and Ulysses, during the Trojan war, to undertake the stealing of it. For this purpose having entered the citadel by night, or by means of secret intelligence, they stole away this valuable pledge of the security of the Trojans, and conveyed it into their camp; where they had scarcely arrived, when the goddess gave testimonies of her wrath

It is said, there was, anciently, a statue of Pallas preserved at Rome, in the temple of Vesta; which some pretended to be the true palladium of Troy, brought into Italy by Æneas: it was kept among the sacred things of the temple, and only known to the priests and vestals. This statue was esteemed the destiny of Rome; and there were several others made perfectly like it, to secure it from being stolen. There was also a palladium in the citadel of Athens, placed there by Nicias.

PALLIER, or Paillier (French) in building, a landing-place in a stair-case, which being broader than the rest of the stairs, serves to rest upon. The term, which is pure French, is not much used by English builders. On large staircases, where there are sometimes several pillars in a range or line, the palliers ought each to have, at least, the width of two steps. Vitruvius calls the palliers on landing-places of the theatres *diazomata.*

PALLIFICATION, or Piling, in architecture, the act of piling the ground-work, or strengthening it with piles, or timber driven into the ground; this plan is adopted upon moist or marshy soils, where an edifice is intended to be erected.

PALM, a measure of length among the Italians, but varying in value in different localities. The palm of Genoa measures nine inches, nine lines, that of Naples eight inches seven lines, that of Palermo eight inches five lines, and the modern Roman palm eight inches three and a half lines.

PALMYRA, *Ruins of,* or Palmyrene Ruins, the ruins of a celebrated city of this name, situate in a desert of Syria, in the pachalic of Damascus, about 48 leagues from Aleppo, and as far from Damascus. This city, under the name of Tadmor, appears to have been originally built by Solomon (1 Kings, ix. 18. 2 Chron. viii. 4.) Josephus assures us, that this was the same city which the Greeks and Romans afterwards called Palmyra; and it is still called Tadmor by the Arabs of the country. But many circumstances besides the style of the buildings, render it probable that the present ruins are not those of the city built by Solomon, though neither history nor tradition mention the building of any other.

With respect to the ruins, they appear to be of two distinct periods; the oldest are so far decayed as not to admit of mensuration, and seem to have been reduced to that state by the hand of time; the others appear to have been broken into fragments by violence. Of the inscriptions, none are earlier than the birth of Christ, nor are any later than the destruction of the city by Aurelian, except one, which mentions Dioclesian. It is scarcely less difficult to account for the situation of this city than for its magnificence; the most probable conjecture is, that as soon as the springs of Palmyra were discovered by those who first traversed the desert in which it is situated, a settlement was made there for the purpose of carrying on the trade to India, and preserving an intercourse between the Mediterranean and the Red Sea. This trade, which flourished long before the Christian æra, accounts not only for its situation, but also for its wealth. As it lay between Egypt, Persia, and Greece, it was natural to expect, that traces of the manners and sciences of those nations should be discovered among the Palmyrenes; who accordingly appear to have imitated the Egyptians in their funeral rites, the Persians in their luxury, and the Greeks in their buildings; and therefore the buildings, which now lie in ruins, were probably neither the works of Solomon, nor of the Seleucidæ, nor, few excepted, by the Roman emperors, but of the Palmyrenes themselves.

Palmyra was formerly encompassed by palms and fig-trees, and covered an area, according to the Arabs, of near ten miles in circumference; and might probably have been reduced to its present confined and ruined state by quantities of sand, driven over it by whirlwinds. The walls of the city are flanked with square towers; and it is probable, from their general direction, that they included the great temple, and are three miles in circumference. But, of all the monuments of art and magnificence in this city, the most considerable is the temple of the sun. The whole space containing its ruins, is a square of 220 yards, encompassed with a stately wall, and adorned with pilasters within and without, to the number of sixty-two on a side. Within the court are the remains of two rows of very noble marble pillars, 37 feet high; the temple was encompassed with

another row of pillars 50 feet high ; but the temple itself was only 33 yards in length, and 13 or 14 in breadth. This is now converted into a mosque, and ornamented after the Turkish manner. North of this place is an obelisk, consisting of seven large stones, besides its capital and the wreathed work about it, about 50 feet high, and, just above the pedestal, 12 in circumference. Upon this there was, probably, a statue, which the Turks have destroyed. At a small distance there are two others, and a fragment of a third, which gives reason for concluding that they were once a continued row. There is also a piazza 40 feet broad, and more than half a mile in length, enclosed with two rows of marble pillars, 26 feet high, and 8 or 9 feet in compass ; and the number of these, it is computed, could not have been less than 560. Near this piazza appear the ruins of a stately building, supposed to have been a banqueting house, elegantly finished with the best sort of marble. In the west side of the piazza there are several apertures for gates into the court of the palace, each adorned with four porphyry pillars, 30 feet long and 9 in circumference. There are several other marble pillars differently arranged, on the pedestals of which there appear to have been inscriptions both in the Greek and Palmyrene languages, which are now altogether illegible. Among these ruins there are also many sepulchres, which are square towers, four or five stories high, and varying in size and splendour. We are indebted for an account of these very magnificent remains of antiquity, partly to some English merchants who visited them in 1678 and 1691, (*Phil. Trans.* No. 217, 218, or Lowthorp's *Abr.* vol. iii.) but chiefly to Mr. Bouverie and Mr. Dawkins, accompanied by Mr. R. Wood, who travelled thither in 1751. The result of their observation was published in 1753, in the form of an Atlas, containing 57 copper-plates, admirably executed. Since this publication, it is universally acknowledged that antiquity has left nothing, either in Greece or Italy, to be compared with the magnificence of the ruins of Palmyra.

PAMPRE, a wreath composed of the leaves and fruit of the vine, employed to decorate the spiral grooves of twisted columns.

PANCARPI, garlands or festoons of flowers, fruit, &c.

PANEL, or Pannel (from the Latin *panellum*, a small pane), in joinery, a tympan, or square piece of wainscot, sometimes carved, framed, or grooved in a large piece, between two mounters or upright pieces, and two traverses or cross pieces. Hence also panels or panes of glass, are compartments, or pieces of glass of various forms ; square, hexagonal, &c.

Panel, in masonry, one of the faces of a hewn stone.

PANNIER, the same as Corbel ; which see.

PANORAMA, a picture exhibiting a succession of objects upon a spherical or cylindrical surface, the rays of light being supposed to pass from all points of external objects, through the surface, to the eye in the centre of the sphere, or axis of the cylinder.

This ingenious pictorial contrivance was first devised by an English artist, Robert Barker, about the year 1794 ; and is not so much a new mode of painting—the process itself being similar to scene-painting, or in distemper—as a novel application of it. Contrary to the diorama [*See* Diorama], the panorama forms the surface of a hollow cylinder, or rotunda (whence it is frequently called, in German, *Rundgemalde*, or *Rundbild*, cyclorama), in the centre of which is a detached circular platform for the spectators, covered over head to conceal the skylight, and thereby increase the illusion, and give greater effect to the painting itself. This latter is not painted on the walls, but upon canvass, like the scenes of a theatre, and afterwards fixed up, in order that the views may be changed, and a fresh one may be in progress while another is open for exhibition. Yet, although there is nothing whatever particular in regard to the execution or process of such pictures, they are attended with difficulties which can be mastered only by practice and experience.

The first of these arises from the circumstance, that the artist cannot either concentrate his light, or adapt the direction of it arbitrarily, as best suits his purpose ; but while portions of his view will be entirely in sunshine, the opposite one will be almost a mass of shadow ; the second is the difficulty of representing, on a curved surface, the straight horizontal lines of buildings ; the third and greatest of all is, that there can be no single fixed point of sight, since the eye traverses around the whole circle of the horizon. Hence it may be supposed, that many parts of such a picture would appear, if not quite distorted, more or less out of perspective. Yet such is not the case, no doubt partly because the eye accommodates itself to certain principal points fixed upon by the artist as centres of vision, and on account of the optical fascination attending the whole. The subjects generally chosen are views of cities, or interesting sites, whose entire locality and buildings may thus be vividly placed before the eye in a manner no less instructive than it is interesting.

Panoramic Projection is the method of forming a panorama from the geometrical consideration of the properties of vision.

In the following principles of the panorama, the surface on which objects are supposed to be represented is that of a cylinder ; though a sphere may be considered still more perfect, as its surface is everywhere equally distant from the eye ; but a cylindric surface is more convenient for the purpose of delineation ; and if the objects are not very distant from the intersection of a plane passing through the eye perpendicular to the axis, the distortion will not be perceptible. We premise the following definitions :

1. The cylindric surface on which objects are to be represented, is called, also, *the panoramic surface ;* and the picture formed is called *a panoramic view*, or *panoramic picture.*

2. *The point of sight* is the place where the organ of vision is placed, in order to receive the impression of the images of the objects on the panoramic picture.

3. *An original object* is any object in nature, or an object which may be supposed to exist, in a given position and distance, as a point, line, or solid.

4. *An original plane* is the plane on which original objects are supposed to be placed.

5. The point where an indefinite original line cuts the picture, is called *the intersection of that original line.*

6. The line on the picture where an original plane meets or intersects it, is called *the intersection of that original plane.*

7. A line drawn through the point of sight parallel to an original line, is called *the parallel of that original line.*

8. A plane passing through the point of sight parallel to any original plane, is called *the parallel plane.*

9. A *surface of rays* is that which proceeds from an original line, or from any line of the original object, by rays from all points of that line terminating in the eye. If the line in the original object be straight, the surface of rays is called *a plane of rays*, *optic plane*, or *visual plane.*

10. When the rays proceed from one or more surfaces of an original object, the whole is called *a pyramid of rays*, or *optic pyramid ;* and if the base be circular, it is called *a cone of rays*, *visual cone*, or *optic cone.*

In every kind of projection from a given point, the projection of a straight line upon any surface is the intersection of

a plane of rays with the surface from all points of the straight line to the given point. Therefore, the panoramic projection of a straight line is the intersection of the cylindric surface and a plane. If a right cylinder be cut by a plane perpendicular to its axis, the section is a circle; if cut parallel to the axis, the section is a rectangle; and if cut obliquely to the axis, the section is an ellipsis. If the surface of the cylinder be extended upon a plane with the sections of the cylindric surface, and a plane cut in each of the positions here stated, the section made by the plane perpendicular to the axis will be a straight line; and the section made by cutting it parallel to the axis will also be a straight line; but the section made by cutting it obliquely will be a curve of similar properties with that known to mathematicians by the name of *the figure of the lines;* therefore, the projection of every straight line in a plane passing through the eye perpendicular to the axis of the cylinder, will also be a straight line on the extended surface; and every straight line in a plane passing through the axis will also be a straight line on the extended surface, perpendicular to that formed by the plane passing through the eye perpendicular to the axis.

The panoramic projection of any straight line not in a plane passing through the eye perpendicular to the axis, nor in a plane passing through the axis, is in the curve of an ellipsis; for in this case the optic rays which cut the cylinder will neither be in a plane parallel to the axis, nor in a plane perpendicular to it.

The panoramic representation of any straight line in a plane perpendicular to the axis, but not passing through the eye, is in the curve of an ellipsis, and the optic plane will be at right angles to another plane passing through the axis at right angles to the original line.

In the panoramic representation of any series of parallel lines, the optic planes have a common intersection in a straight line passing through the eye, and the common intersection will be parallel to each of the original straight lines; therefore, the indefinite representations will pass through the extremities of the common intersection.

In the panoramic representation of any series of parallel lines in a plane perpendicular to the axis, but not passing through the eye, the common intersection of the optic planes is parallel to the plane on which the original lines are situated.

In the indefinite representations of any number of straight lines parallel to the axis, the visual planes will have a common intersection in the axis, and will divide the circumference of the cylinder into portions which have the same ratio to each other as the inclination of the visual planes.

If an original straight line parallel to the axis be divided into portions, the representations of the portions will have the same ratio to each other as the originals.

If in any original plane there be a series of straight lines parallel to each other, and also another series of straight lines parallel to each other, and at any given angle with the former series, the common intersections of the visual planes will make the same angle with each other, which any line of the one series makes with any one of the other series, and the common intersections will be in a plane parallel to the original plane; and, therefore, if the original plane be perpendicular to the axis, the common intersections of the visual planes will also be in a plane perpendicular to the axis. Hence the common intersections of visual planes from any two systems of straight lines, parallel to any two straight lines at a given angle with each other in a plane perpendicular to the axis, are also in a plane perpendicular to the axis, and make the same angle with each other which the two lines in the original plane make with each other.

11. The two points where the parallel of an original line inclined to the axis of the cylinder meets the panoramic surface, are called *the vanishing points of that original line.*

12. The intersection of the parallel of an original plane is called *the vanishing line of that plane.*

13. A straight line drawn from any point in the axis of the cylinder, at right angles to the same, to meet the panoramic surface, is called *the distance of the picture.*

14. *The centre of a plane parallel to the axis*, is the point where a straight line from the eye perpendicular to the plane meets it.

15. *The panoramic centre of a plane parallel to the axis*, is the point where a straight line drawn from the eye perpendicular to the plane, cuts the picture.

16. *The station point*, is the point where the axis intersects the original plane.

17. *The centre of an original line*, is the point where a straight line, drawn from the station point perpendicular to the original line, cuts the original line.

18. *The panoramic centre of an original line*, is the point where a straight line, drawn from the station point perpendicular to the original line, cuts the picture.

19. *The distance of an original plane parallel to the axis from the picture*, is the straight line drawn from the panoramic centre to the centre of the original plane.

20. *The distance of an original line from the picture*, is the straight line drawn from the panoramic centre to the centre of the original line.

21. *The distance of an original plane*, is the straight line drawn from the eye to the centre of the original plane.

22. *The distance of an original line*, is the straight line drawn from the station point to the centre of the line.

An original line parallel to the axis of the panorama has no vanishing points.

An original plane parallel to the axis of the panorama has two vanishing lines.

The vanishing line of a plane perpendicular to the axis of the panorama, is a circle on the panoramic picture; but if the panoramic surface be extended upon a plane, it becomes a straight line.

The vanishing lines of all planes inclined to the axis are ellipses, and when extended upon a plane become sinical curves, which are also termed *panoramic curves*, as being the only kind of curve which the cylindric picture produces when developed.

Problem I.—*Plate* I.—*Figure* 1.—*To describe the panoramic curve to given dimensions.*—Let A B be the length of the curve; bisect A B in C, draw C D perpendicular to A B; make C D equal to the deflection of the arc from the chord A B; from the point C, with the distance C D, describe the quadrant D E; divide the arc D E into any number of equal parts, (say four) also divide either half, C B, into the same number (four) of equal parts; let *l*, *i*, *g*, be the points of division in the quadrantal arc; draw *l k*, *i h*, *g f*, perpendicular to A B, cutting it at *k*, *h*, *f*; and let K, H, F, be the points of division in C B; draw K L, H I, F G, perpendicular to A B; make K L, H I, F G, respectively equal to *k l*, *h i*, *f g*; construct perpendiculars upon C A, in the same manner; through all the points G, I, L, D, describe a curve, which will be that of the panorama.

The curve A D B is that which would be found by cutting a semi-cylinder, whose circumference is A B, at an altitude, C D, distant on the surface from a plane perpendicular to the axis, at a quadrant distance from the point A or B in the extremity of the diameter of the plane perpendicular to the axis. Therefore the whole panoramic curve will be double the length of A B; the other part being a similar and equa[l]

curve above the line A B, produced, and consequently a curve of contrary flexure.

The panoramic curve takes place when the cylinder is cut by a plane at oblique angles to the axis.

PROBLEM II.—*To find the indefinite representation of lines parallel to the original plane, in a plane parallel to the axis of the picture; given the height of the eye, the intersection of the original plane, and the distance of the original plane from the picture.*

Figure 2, No. 1.—Let P be the station point; G K H I the intersection of the picture; and A B a line in the original plane, on which the plane parallel to the axis stands.

In *Figure* 2, No. 5, draw P K, which make equal to P K, No. 1. In No. 5, draw P O and K *w* perpendicular to P K; make P O equal to the height of the eye; draw O *w* parallel to P K; produce P K to *r*; in No. 1, draw P *r* perpendicular to A B, cutting A B at *r*, and the intersection of the original plane with the panoramic surface at K; make P *r*, No. 5, equal to P *r*, No. 1: draw *r s* perpendicular to K P: in No. 5, make *r t*, *t u*, *u v*, equal to the height of the several lines, whose indefinite representations are required, above the original plane; produce O *w*, meeting *r s* at *s*; produce K *z* to meet O *s* at *w*; draw O *r*, O *t*, O *u*, and O *v*, cutting K *w* respectively at *v*, *x*, *y*, and *z*. In No. 2, make G H equal to the semi-circumference G K H, No. 1; bisect G H at *w*; draw *w v* perpendicular to G H; make *w v*, *w x*, *w y*, and *w z*, respectively equal to *w v*, *w x*, *w y*, and *w z*, No. 5; then with the common length G H, and the deflections *w v*, *w x*, *w y*, and *w z*, describe the curves G *v* H, G *x* H, G *y* H, G *z* H, which will be the development of the representation of the lines required, and G and H will be their vanishing points. For O P *r s*, No. 5, may be considered as a plane passing along the axis of the cylinder; O P the axis, O the eye, P the station point, K *w* a section of the cylindric surface, and O *r*, O *t*, O *u*, and O *v*, visual rays; and, consequently, the points *v*, *x*, *y*, *z*, will be the representations of *r*, *t*, *u*, *v*; and since *r*, *t*, *u*, *v*, may be considered as the centres of the original lines, whose representations are required, and since the optic planes of these lines cut the cylinder obliquely, the sections will be elliptical, and, consequently, their envelope will be the figure of the sines, as here described.

PROBLEM III.—*To describe the representation of a line in a plane perpendicular to the axis of the cylinder, giving the seat of the line on the original plane.*

In No. 2, draw G *d* perpendicular to G H; make G *d* equal to the descent or deflection of the curve, and describe the quadrantal sinical curve *d w*, and *d w* will be the representation of a line perpendicular to the plane, in which the originals of G *v* H, G *x* H, G *y* H, and G *z* H, are situated.

PROBLEM IV.—*Given the indefinite representation*, G *z* H, No. 2, *of a straight line, to determine the finite portion, whose seat is* A B, No. 1.

Draw P A and P B, No. 1, cutting the intersection at *a* and *b*; make *w a*, No. 2, equal to the extension of K *a*, No. 1; and *w b*, No. 2, equal to the extension of K *b*, No. 1; draw *a* a^{I} and *b* b^{I}, No. 2, perpendicular to G H, cutting the curve G *z* H at a^{I} and b^{I}, and a^{I} *z* b^{I} will be the finite portion required; a^{II} *y* b^{II}, a^{III} *x* b^{III}, and a^{IV} *v* b^{IV}, will be the same portions of the indefinite representations G *y* H, G *x* H, and G *v* H.

The following examples show the application of the principles in the representation of solid objects.

Example 1. *Figure* 2, No. 1.—Let C D E F, be the plan of a house, in contact with the picture at C. Through the station point P, draw G H, parallel to D C, cutting the intersection of the panoramic picture in the points G and H; also through P draw K I, parallel to E D, or F C, cutting the picture in I and K; then G and H are the vanishing points of all lines parallel to E F or D C, and I and K the vanishing points of all lines parallel to C F or D E; draw F P and D P, cutting the picture at *f* and *d*. Let W V be the ridge of the building, bisecting E D at W, and E C at V; produce W V to Y, cutting I K at U; make U Y equal to the height of the house, Nos. 3 and 4; and make the angle U Y Z equal to half the vertical angle of the roof, and let Y Z cut I K at Z; draw X Q parallel to Y Z, cutting K I, or K I produced at Q; draw Z *x* parallel to V W; produce E D to *x*, and F C to meet *x* Z at T; join Q *x* and Q T, which are the intersections of the optic planes formed by the inclined side of the roof, and the vertical planes standing upon D E and C F; draw I N parallel to P O, and O N parallel to I P. To find the inclination of the optic planes; draw P M perpendicular to *x* Q, cutting *x* Q at *u*, and the panoramic intersection at M; from P, with the distance P *u*, describe the arc *u* J, cutting P I at J; join O J; produce N I and O J to meet each other in S. In like manner, draw P *t* perpendicular to T Q, cutting T Q at *v*, and the panoramic intersection at *t*; from P, as a centre, with the radius P *v*, describe the arc *v w*, cutting I P at *w*; join O *w*; produce N I and O *w* to meet each other in R; then N O S is the inclination of the optic plane, whose intersection is Q *x*; and N O R is the inclination of the optic plane, whose intersection is Q T.

Figure 2, No. 6.—Upon any convenient line, I H, extend the panoramic intersection; according to the corresponding places of No. 1, as shown by similar letters; that is, I *t*, *t* G, G *d'*, *d* C', C' *f*, *f'* K, and K H, No. 6, would cover I *t*, *t* G, G *d'*, *d'* C', C' *f*, *f'* K, and K H, No. 1. In No. 6, draw *t* R, G *o*, *d'* *d*, C' *o*, *f'* *f*, K *k* perpendicular to I H.

In No. 5, produce K P to *a*; make P *a* equal to the radius of the cylinder; through *a* draw *i o* parallel to O P; on P *a* make P *j* equal to P *j*, No. 1, and P *q*, No. 5, equal to P *q*, No. 1; draw *j g* and *q h*, No. 5, perpendicular to P *a*; make *q h* and *j g* each equal to the height of the walls, Nos. 3 and 4; join O *g* and O *h*; produce O *g* to *l*, and O *h* to *i*, meeting *o i*; produce O *j* and O *q* to meet G *o* at *o* and *k*.

In No. 6, make *t* R equal to N R, No. 1; G *o* equal to G *o*, No. 5; G *l* equal to G *l*; K *k* equal to G *k*; K *i* equal to G *i*; describe the panoramic curves I *l* K, I *o* K, G *k* H, G *i* H; then the curves I *o* K and G *k* H will cut each other at *c*, and the curves I *l k*, G *i* H, will cut each other at C, so that the points C', C, *c*, will be in the same perpendicular; C *c* will thus represent the angular line of the building. Let the perpendicular *d' d* cut the curve G *i* H at D, and the curve G *k* H at *d*; and the intercepted portion D *d* is the angular line at one end; in like manner, let the perpendicular *f' f* cut the curve I *l k* at F, and the curve I O K at *f*; and the intercepted portion F *f* of the perpendicular *f' f*, is the representation of the angular line at the other end; therefore *c* C D *d* represent the front, and *c* C F *f* the end, exclusive of the triangular part adjoining the roof, which will be formed in the following manner: make *t x* and *x u* equal to G K each; describe the same panoramic curve, R C *x*; and if the other semi-panoramic curve, *x v w*, is described, and if *k* K be produced to *v*, *v* will be the vanishing point for the gable top; and if K *n* be made equal to K, *v*, *n* will be the vanishing point of the other inclined plane of the roof; and thus the representation of lines and planes will have vanishing points and vanishing lines, as in the methods of describing the perspective representation of objects upon a plane surface; and if the points *d*, D, *c*, C, *f*, F, are found, and the lines *c d*, C D, and *c f*, C F, are made straight instead of being curved and produced, they will find their own vanishing points in the line I H; but more remote from each other than the points G and K.

What is here observed, is exemplified in No. 7, as will appear sufficiently clear by a little reflection.

The example here shown is very distorted, on account of the smallness of the panoramic cylinder, and the size of the object, which was obliged to be very large, in order to give a clear elucidation of the principles.

Example 2.—*Figure* 3, shows the panoramic representation of a row of houses, upon the surface of a cylinder of greater radius than that of *Figure* 2, No. 1, where the pictural objects appear much more agreeable to the eye than that of *Figure* 2; the lines which form the roofs are in this example represented as straight, though in reality they are curves, as a great deal of trouble is saved, and the error occasioned by their introduction is too trifling to be observed.

It remains to show the truth of the operations used in the construction of *Figure* 2. Let it now be proved that *x* Q and T Q are the intersections of the optic planes, formed by the inclined lines of the gables. From the definition given, an optic plane is one passing along an original line, and through the eye; therefore, if a straight line be drawn through the eye parallel to the original line, the line, thus passing through the eye, and the original line, will both be in the same plane, that is, both in the optic plane; and if two planes be drawn along two parallel lines, their intersections with a third plane will be parallel; now the parallels F T and K I are the intersections of two parallel planes; F T that of the vertical plane, in which the inclined original line is situated, and K I that in which the eye is situated, or in which the line parallel to the inclined line is situated; the point T is the intersection of the inclined line of the roof, and the point Q the intersection of the line drawn through the eye parallel to the inclined line of the roof; therefore the optic plane will pass through the points T and Q, and consequently T Q is the intersection of the optic plane and the original plane. In the same manner, it may be shown that *x* Q is the intersection of the optic plane, formed by the other inclined line of the farther gable in the same plane with the former line.

Next let it be shown that the angles N O S and N O R, No. 1, are the inclinations of the optic planes, whose intersections are *x* Q and T Q. The inclination of any two planes is measured by a third plane, perpendicular to their common intersection; now T Q is the intersection of the optic plane, and P *v* is perpendicular to T Q; and because P *w* is equal to P *v*, and P *o* perpendicular to P *w*, and equal to the height of the eye; conceive the plane of the triangle *w* P O to be raised perpendicular to the original plane, so that the base P *w* may coincide with P *v*; then O will represent the eye in its true place, and the point *w* will be upon *v*; and since the intersection T Q would be perpendicular to the plane of the triangle, every line drawn in the plane of the triangle from *v*, would be perpendicular to the intersection T Q, and consequently, the line drawn in this plane from *v* to O, would also be perpendicular to the intersection; therefore the angle P *w* O is the inclination of the plane, and, consequently, the alternate angle N O R. In the same manner, it may be shown, that N O S is the inclination of the plane whose intersection is *x* Q.

Now to show that N R is the deflection of the curve made by the optic plane, it only requires to be considered, that the transverse axis of the ellipsis made by the optic plane, is in the plane which measures the inclination of the optic plane to the original plane: for this purpose, P O N R may be considered as a semi-section of the cylinder along the axis, and N R a section upon the surface; therefore O R will represent half the greater axis, and N R the deflexion of the curve, or its descent below the vanishing line of the horizon. *Figure* 2, No. 5, is also to be considered as a section of the cylinder, of which O P represents the axis, G *o* and *w* K the sides: and because the appearance of all points in the same plane perpendicular to the axis, at equal distances from the station point, will be at the same height on the surface from the original plane, or from the plane passing through the eye parallel to the original plane, their heights will be found by setting their distances upon P *a*, then erecting lines perpendicular to P *a*, from each point of the section; then setting the heights of the points upon these lines, and drawing lines from O, through the top of each perpendicular till they cut G *o*; then the distance from G, to each point of section, gives the distance of each point from the plane passing through the eye upon the panoramic surface.

Now let the cylinder be conceived to be enveloped by No. 6, so that I H may fall upon the circumference of a circle in a plane perpendicular to the axis; then every line will fall in its true position, and the representative object will produce the same pyramid of rays as the original, the eye being supposed to be fixed at its true distance above the line I H; and, consequently, nothing more will be required to excite an idea of the existence of the object, than to give the representative surfaces their proper colours, light, and shade, according to the distance of the original. Hitherto straight lines have been represented by portions of the sinical curve when extended, or by portions of an ellipsis, when the sheet on which the objects are represented, is brought in contact with the surface of the cylinder, as they ought properly to be; but if the radius of the cylinder is of sufficient extension, and the objects to be represented of proper magnitude, any attempt to represent straight lines by curves from the hands of an artist would be absurd, except when the object to be represented is very near to the panoramic surface, in which case a curvature in the line may be sensible, also at a moderate distance: the curve can only be observed in a series of objects in a straight line; it will therefore be sufficient to represent the straight lines of each individual object by straight lines also, but to preserve the curve, or rather the polygonal figure inscribed in the sinical curve in the series, as the inflexions or angles will hardly be visible.

A straight line will therefore be represented by finding the representation of its extremities, and joining the representative points; but if it is of great extent, it may be obtained by finding a number of points, and joining every two adjoining points in succession by a straight line, and the whole will assume the form of a curve, which will be the representative of the straight line.

Plate II. shows a series of figures, such as may be supposed to constitute the whole of the practice of representing panoramic objects. S is the station point; the objects are referred to in alphabetical order from A, B, C, &c. to H; each extreme point of the linear parts of the same object has the same letter affixed, with a numerical index, which increases, by unity, in tracing round the circumference in progressive order. The points where the optic lines cut the panoramic surface, are numbered with the same figure from the same object, each number having an index corresponding to that of the point of the object to be represented. The numbers are placed in successive order, agreeing with that of the alphabet. No. 1, the intersection of the panorama and the original plane, with the figures of the objects to be represented.

No. 2, 3, 4, vertical sections of the panorama, passing along its axis, in order to ascertain the heights of the several places of each object; E the point of sight, or place of the eye; S the station point; P Q a section of the cylinder, showing the heights of the objects.

The objects to be represented are, A, a point, the optic ray from which cutting the intersection at 1; B a straight line, the optic ray from which cutting the intersection at

2^1 2^2; C a line standing upon C, the optic ray from which cutting the intersection at 3; D an inclined plane, whose seat is represented by D^1, D^2, the optic rays from which cutting the intersection at 4^1, 4^2; E an angle, the optic rays from which cutting the intersection at 5^1, 5^2, 5^3; F a triangle, the optic rays from which cutting the intersection at 6^1, 6^2, 6^3; G a rectangle, the optic rays from which cutting the intersection at 7^1, 7^2, 7^3, 7^4; and, lastly, H a circle, the optic rays from which cutting the intersection at 8^1, 8^2, 8^3.

The distances of the objects are placed upon the panoramic sections No. 2, 3, 4, from S, upon the lines S P, or upon S P produced; then drawing lines from the points to E, give the heights upon P Q.

The perpendicular standing upon C, No. 1, is thus found: in No. 3, draw C C from C, perpendicular to S P, equal to the height of the perpendicular upon C No. 1, and draw the straight lines C E, C E, No. 3, cutting P Q at 3 3, then 3 3 is the panoramic length of C C. The upper extremity of the inclined line, D, will be found by ascertaining the panoramic height of the perpendicular, from the elevated end to the original plane. No. 5 shows the panoramic representation of the several objects; V L the vanishing line of the horizon; the intersections of the optic rays are extended upon V L from No. 1, the references upon the intersection No. 1, and upon V L, No. 5, being the same. The heights of the several points are taken from the sections No. 2, 3, and 4, from Q downwards towards P, and placed from the corresponding points in V L, No. 5, also downwards upon the perpendiculars, gives the several points of the objects; thus a is the representation of the point A, No. 1; b^1, b^2, of B^1, B^2, &c. In the circle, the points for half the curve are found, the other half being repeated in the same order from the middle line, each line serving for two points, so that the three lines give eight points; the extreme lines are tangents which are equivalent to two points.

The points around the circumference of the intersection No. 1, are extended upon V W and X Y, according to the principle of Renaldinus, by setting three-fourths of the radius, without the circle, upon the opposite side of the tangents V W, and X Y, and transferring the divisions of V W and X Y upon V L, No. 5, gives the points corresponding to the intersection.

The panoramic surface being enveloped by No. 5, and the representations of the objects placed in their true position, will form the same picture at the point of sight, if correctly painted, as the objects themselves would in nature.

A practical method of forming all straight lines on the panoramic surface in its place, without development, is to ascertain the position of the objects, also the heights of the centres of the lines to be represented; then fixing the eye in its position, and holding a straight-edge parallel to the line to be drawn in a plane with the point of sight and the point representing the centre of the line, mark several points in the same plane, on the panoramic surface; these points being joined, will give the representation of the line required. In preparing for panoramic projections, whatever objects are intended to be represented, a proper point of view should be chosen from this situation; a sketch of all the surrounding objects should be made according to the development of the panorama; for though the painting itself may be performed upon the cylindric surface, it is more eligible to sketch upon a plane. The next thing to be done is to take a survey of the objects, observing their positions to each other; then, with a plane table fixed on the point of view, quite level, take the successive angles of the surrounding objects by means of a moveable limb, which may carry two pieces, one at each extremity, perpendicular to the surface of the plane table; one piece being fixed in the supposed axis of the panorama, containing a sight-hole for the point of view, so that the moveable part will consist of three bars, the bottom one serving as a straight edge for drawing the angles of position: the heights of the object may be marked upon the other limb parallel to that fixed in the axis; and let it be observed, that the point of view in the axis, the edge of the limb which gives the heights of the objects, and the edge of the bottom bar by which the angles are drawn, must be in a plane passing along the axis: mark the vertical lines on the sketch, and the lines on the plane table, which show their position, with corresponding characters, otherwise it would be difficult to distinguish what the numerous lines apply to. The moveable edge of the index, which describes the circumference of the cylinder, should be of ivory, as the various heights may be marked with pencil, and rubbed out at pleasure, as these heights may be transferred to a piece of paper, marking them with the same character as that of the sketch, and with the addition of the words *top of chymney, shaft, ridge of roof top of wall*, &c., as the heights may be the terminations of such parts of the said objects, or, instead of writing any word, a slight representation may be drawn of the parts of the object.

Instead of the ivory edge of the bar, which describes the panoramic surface, a slit, or very narrow aperture, formed by a double bar, may be used. The tendency of every line, horizontal or inclined, may be found by a fifth bar, moveable round a centre, which centre must also be moveable upon the edge of the limb which gives the panoramic heights of the objects; the plane in which this fourth bar moves must be a tangent to the panoramic surface, at the line which is intersected by the plane passing along the axis, along the straight-edge of the bottom bar, and along the edge where the heights of the objects are marked; then if the edge of this fourth moveable bar be brought in a plane with the eye and the original line, the angle which it forms with the edge of the vertical limb is the inclination of the line on the picture.

PANT, a conduit for water.

PANTHEON, (from the Greek *παν*, *all*, and *θειον*, *gods*,) in architecture, a temple or church, of a circular form, dedicated to all the gods, or to all the saints.

The Pantheon of ancient Rome is of all these edifices the most celebrated, and that from which all the rest take their name. It was built by Agrippa, son-in-law to Augustus, in his third consulate, twenty-five years before the Christian era; though several antiquaries and artists have supposed that the Pantheon existed long before, during the commonwealth, and that Agrippa only embellished it and added the portico. To this purpose they allege the authority of Dion Cassius, who, speaking of Agrippa, says, he also finished or perfected the Pantheon.

It was dedicated by him to Jupiter Ultor, Jupiter the Avenger, according to Pliny's account; according to Dion Cassius, to Mars, Venus, and Julius Cæsar; but, according to the most probable opinion, to all the gods; and had the name *Pantheon*, on account of the great number of statues of the gods, raised in seven niches all round it; and because it was built of a circular form, to represent heaven, the residence of the gods, or, because it was dedicated to all the gods, (*quasi παντον θειον.*) It had but one door. It was 144, or, as Fabricius says, 140 feet diameter within, and just as much in height, and of the Corinthian order. The roof was curiously vaulted, void spaces being left here and there for greater strength. The rafters, 40 feet long, were plated with brass. There were no windows in the whole edifice; but sufficient light was let in through a round hole in the top of the roof. Before each niche were two columns of antique yellow marble, fluted, each of one entire block.

The whole wall of the temple, as high as the grand cornice inclusive, was cased with divers sorts of precious marble in compartments; and the frieze was entirely of porphyry. The outside of the front was anciently covered with plates of gilt brass, and the top with plates of silver; in lieu of which, lead was afterwards substituted. The gates were of brass, and of extraordinary size and workmanship. The eruption of Vesuvius, in the reign of Tiberius, and a great fire in the reign of Titus, damaged the Pantheon very considerably; but it was successively repaired by Domitian, Adrian, and Septimius Severus: and having subsisted in all its grandeur till the incursion of Alaric, in the reign of Honorius, it was then stripped of several of its statues and ornaments of gold and silver. About thirty-nine years after this, Genseric, king of the Vandals, took away part of its marbles and statues; and, at length, Pope Boniface IV. obtaining this Pantheon of the Emperor Phocas, converted it into a church, without any alteration in the building, and dedicated it to the Virgin and all the martyrs; but, in 1665, Constantius II. stripped it of its inside and outside brazen coverings, which he transported to Syracuse. It still subsists at Rome, under the title of Notre Dame de la Rotonda.

The square of the Pantheon, or *Piazza della Rotonda*, is adorned with a fountain and an obelisk, and terminated by the portico of Agrippa. This noble colonnade consists of a double range of Corinthian pillars of red granite. Between the middle columns a passage opens to the brazen portals, which, as they unfold, expose to view a circular hall of immense extent, crowned with a lofty dome, and lighted solely from above. It is paved and lined with marble. Its cornice of white marble is supported by sixteen columns, and as many pilasters of Giotto antico; in the circumference there are eight niches, and between these niches are eight altars, adorned each with two pillars of less size, but the same materials. The niches were anciently occupied by statues of the great deities; the intermediate altars served as pedestals for the inferior powers. The proportions of this temple are admirable for the effect intended to be produced; its height being equal to its diameter, and its dome not an oval, but an exact hemisphere. The Pantheon is the most noble and perfect specimen of Roman art and magnificence which time has spared, or the ancients could have wished to transmit to posterity. It has served, in fact, as a model to succeeding generations, and to it Constantinople is indebted for Santa Sophia, and to it Rome, or rather the universe, owes the unrivalled dome of the Vatican. Upon the whole, this is the most ancient edifice that now remains in a state of full and almost perfect preservation.

There was also another Pantheon at Rome, dedicated to Minerva, as the goddess of medicine. It was in form of a decagon, and the distance from one angle to another measured 22½ feet. Between the angles there were nine chapels of a round figure, designed for so many deities: and over the gate there was a statue of Minerva.

The Pantheon of Nismes, was a temple in that city, in which were twelve niches, for statues supposed to have been destined for the twelve great gods.

The Pantheon of Athens was, in many respects, little inferior to that at Rome, built by Agrippa. The Greek Christians converted it into a church, dedicated to the Virgin, under the name of *Panegia*, but the Turks changed it into a mosque.

In the Escurial is a magnificent chapel, called Pantheon, 35 feet in diameter, and 38 high from the pavement, which is of marble and jasper inlaid. The whole inside of the chapel is of black marble, except the lantern, and some ornaments of jasper and red marble. In this chapel are deposited the bodies of the kings and queens: there are only places made for twenty-six, eight of which are already filled.

PAN-TILES, *see* TILES.

PANTOMETER, an instrument for measuring all sorts of elevations, angles, and distances.

PAPER, *Drawing*, a stout coarse kind of paper used for drawing upon, of which sheets are manufactured of the following sizes:

	Inches.		Inches.
Demy	20 by 15	Atlas	34 by 26
Medium . . .	22 " 17	Double Elephant	40 " 26
Royal	24 " 19	Antiquarian .	52 " 31
Super royal . .	27 " 19	Extra-Antiquarian	56 " 40
Imperial . . .	30 " 21	Emperor . . .	68 " 48
Colombier . .	34 " 23		

PARABOLA, (from the Greek παρα, *through*, and βαλλω, *to throw*) in geometry a curve line made by the common intersection of a conic surface and a plane which cuts it, and is parallel to another plane that touches the conic surface.

A conic section made by a plane ever so little inclined to the parabola on the one side, is an ellipsis; and a section made by a plane inclined ever so little on the other side, is an hyperbola; thus the parabola is the limit between these two curves, to which they both continually approach, while their transverse axes increase more and more; being, as it were, the passage from one of them to the other.

PARABOLA, a plain figure, bounded by a curve and a straight line, possessing the property that $a\,x = y^2$; in which x is the abscissa, and y the ordinate.

PARABOLIC ASYMPTOTE, in geometry, a parabolic line approaching to a curve, but never meeting it; yet by producing both indefinitely, their distance from each other becomes less than any given line.

There may be as many different kinds of asymptotes as there are parabolas of different orders.

When a curve has a common parabola for its asymptote, the ratio of the subtangent to the abscissa approaches continually to the ratio of two to one, when the axis of the parabola coincides with the base; but this ratio of the subtangent to the abscissa approaches to that of one to two, when the axis is perpendicular to the base. And by observing the limit to which the ratio of the subtangent and abscissa approaches, parabolic asymptotes of various kinds may be discovered.

PARABOLIC CONOID, *See* PARABOLOID.

PARABOLIC CURVE, the curved boundary of a parabola which terminates its area, except at the double ordinate.

PARABOLIC SPIRAL, or HELICOID, a curve arising from a supposition of the axis of the common parabola being bent into the periphery of a circle while the ordinates are portions of the radii next to the circumference.

PARABOLOID (from παραβολη and ειδος) a solid formed by the revolution of a parabola about its axis. It is described by Harris as a parabolic firm curve, whose ordinates are supposed to be in subtriplicate, subquadruplicate, &c., ratio of their respective abscissas.

PARADIGRAMMATIZE, (from the Greek παραδειγμα, *an example*, and γραμμα, *a letter*) the act of forming all sorts of figures in plaster. The artists themselves are called *gypsochi*. Neither term is much used.

PARADOX (from the Greek παρα, *against*, and δοξα, *opinion*) in philosophy, a proposition seemingly absurd, because contrary to the received opinions; but yet true in effect.

The Copernican system is a paradox to the common people; but the learned are all agreed as to its truth.

Geometricians have been accused of maintaining paradoxes; and, it must be owned, that some use very mysterious terms in expressing themselves about asymptotes, the sums of infinite progressions, the areas comprehended between curves and their asymptotes, and the solids generated from these areas, the length of some spirals, &c. But all these paradoxes and mysteries amount to no more than that the line or number may be continually acquiring increments, and those increments may decrease in such a manner, that the whole line or number shall never amount to a given line or number.

The necessity of admitting this is obvious from the nature of the most common geometrical figures; thus, while the tangent of a circle increases, the area of the corresponding sector increases, but never amounts to a quadrant. Neither is it difficult to conceive, that if a figure be concave towards a base, and have an asymptote parallel to the base (as it happens when we take a parallel to the asymptote of the logarithmic curve, or of the hyperbola, for a base) that the ordinate in this case always increases while the base is produced, but never amounts to the distance between the asymptote and the base. In like manner, a curvilinear area may increase while the base is produced, and approach continually to a certain finite space, but never amount to it; and a solid may increase in the same manner, and yet never amount to a given solid.

A spiral may in like manner approach to a point continually, and yet in any number of revolutions never arrive at it; and there are progressions of fractions, which may be continued at pleasure, and yet the sum of the terms shall be always less than a given number. In Maclaurin's *Fluxions* (book i. ch. 10. *et seq.*) various rules are demonstrated, and illustrated by examples, for determining the asymptotes and limits of figures and progressions, without having recourse to those mysterious expressions which have of late years crept into the writings of mathematicians. For, as that excellent author observes elsewhere, though philosophy has, and probably always will have, mysteries to us, geometry ought to have none.

PARALLEL, (from the Greek παραλληλος,) in geometry, a term applied to lines, figures, and bodies, which are every where equidistant from each other; or which, though infinitely produced, would never approach nearer to, nor recede farther from, each other.

Parallel Copings, such copings as have their upper surface parallel to the bed of the stone, as in those which cover the gable of a house.

Parallel Right Lines, such lines, as, though infinitely produced, could not meet at any finite distance.

Parallel Motion, among practical mechanics, denotes the rectilinear motion of a piston-rod, &c., in the direction of its length; and contrivances, by which such alternate rectilinear motions are converted into continuous rotatory ones, or *vice versa*, for pumps, steam-engines, saw-mills, &c., are usually called *parallel motions* or *parallel levers*. The object of the parallel motion is, to convert the motion of the end of a reciprocating beam or lever, into a vertical or rectilinear motion; or the continuous motion of a crank at once into a reciprocating motion.

The simplest and most obvious method of producing either of these effects, is to connect the end of the piston-rod to the beam, or the crank, by means of joints, with a connecting rod of a proper length between them, and confine the former, to preserve its rectilinear movement, by sliding through a collar, or in grooves. Friction wheels may be used to make it work easily; but in machines which have great strains, the constant wear of the grooves or wheels, would soon produce looseness, and destroy the parallelism of the motion: recourse must, therefore, be had to parallel levers.

Parallel Planes, those which if produced cannot meet at any finite distance.

Parallel Ruler, *See* Instruments.

Parallel Cut, in inland navigation, a counter drain, to carry off water, and prevent the adjoining lands from being flooded.

PARALLELOPIPED, (from the Greek παραλληλος, *parallel*) in geometry, one of the regular bodies, or solids, comprehended under six parallelograms, the opposite sides of which are similar, parallel, and equal.

A parallelopiped is by some defined an upright prism, whose base is a parallelogram, and the planes of whose sides are perpendicular to the plane of the base.

A rectangular parallelopiped is one whose bounding planes are all rectangles, and which stand at right angles to each other. Every rectangular parallelopiped is said to be contained under the planes that constitute its length, breadth, and altitude.

It is demonstrated, that if from one of the angular points of any parallelogram, a right line be elevated above the plane of the parallelogram, so as to make any angles with the contiguous sides of it, and there be also drawn, from the three remaining angular points, three other right lines parallel and equal to the former, and the extremes of these lines be joined, the figure thus described will be a parallelopiped. If the angle of the parallelogram be right, and the elevated line be erected perpendicular to the plane of the base, then will the parallelopiped be a rectangular one.

Parallelopiped, *Properties of the.* All parallelopipeds, prisms, and cylinders, &c., whose bases and heights are equal, are themselves equal.

Every upright prism is equal to a rectangular parallelopiped of equal base and altitude.

A diagonal plane divides the parallelopiped into two equal prisms: a rectangular prism, therefore, is half a parallelopiped upon the same base, and of the same altitude.

All parallelopipeds, prisms, cylinders, &c., are in a ratio compounded of their bases and altitudes; wherefore, if their bases be equal, they are in proportion to their altitudes; and conversely.

All parallelopipeds, cylinders, &c., are in a triplicate ratio of the homologous sides; and also of their altitudes.

Equal parallelopipeds, prisms, cones, cylinders, &c., are in the reciprocal ratio of their bases and altitudes.

Rectangular parallelopipeds, contained under the corresponding lines of three ranks of proportionals, are themselves proportionals.

To measure the surface and solidity of a parallelopiped.— Find the areas of the parallelograms I L M K, L M O N, and O M K P (*See* Parallelogram); add these into one sum, multiply that sum by 2, and the product will be the surface of the parallelopiped.

"If, then, the base, I L M K, be multiplied by the altitude, M O, the product will be the solidity.

Suppose L M = 36, M K = 15, M O = 12; then L I K M = 36 × 15 = 540; L M O N = 36 × 12 = 432; M O K P = 15 × 12 = 180. The sum of which is = 1152, which multiplied by 2, gives the superficies equal to 2304. And 540 × 12 gives the solidity equal to 6480. Or the solid content of a parallelopiped may be obtained by multiplying the area of the base by the altitude of the parallelopiped. Thus, if the two dimensions of the base be 16 and 12 inches, and the height of the solid 10 inches; then the area of the base being 192, the content of the solid will be 1920 cubical inches.

The parallelopiped with oblique angles is a figure very common to many kinds of stones, especially of the softer sort.

PARALLELOGRAM, (from the Greek παραλληλος, *a parallel*, and γραμμα, *a figure*) in geometry, a quadrilateral right-lined figure, whose opposite sides are parallel and equal to each other.

A parallelogram is generated by the equable motion of a right line always parallel to itself.

When the parallelogram has all its four angles right, and only its opposite sides equal, it is called *a rectangle*, or *an oblong*.

When the angles are all right, and the sides are all equal, it is called *a square*, which some make a species of parallelogram, others not.

If all the sides are equal, and the angles unequal, it is called *a rhombus*, or *lozenge*.

If both the sides and angles be unequal, it is called *a rhomboides*.

Every other quadrilateral, whose opposite sides are neither parallel nor equal, is called *a trapezium*. See each of these articles.

In every species of parallelogram, a diagonal divides it into two equal parts; the angles diagonally opposite are equal; the opposite angles of the same side are, together, equal to two right angles; and every two sides are, together, greater than the diagonal. Every quadrilateral, whose opposite sides are equal, is a parallelogram.

Two parallelograms on the same, or on an equal base, and of the same height, or between the same parallels, are equal. Hence two triangles on the same base, and of the same height are also equal; as are all parallelograms or triangles whatever, whose bases and altitudes are equal among themselves.

Hence, also, every triangle is half a parallelogram upon the same or an equal base, and of the same altitude, or between the same parallels. Hence, also, a triangle is equal to a parallelogram having the same base and half the altitude, or half the base and the same altitude.

Parallelograms, therefore, are, in a given ratio, compounded of their bases and altitudes. If then the altitudes be equal, they are as the bases; and conversely.

In similar parallelograms and triangles, the altitudes are proportional to the homologous sides; and the bases are cut proportionally thereby. Hence similar parallelograms and triangles are in a duplicate ratio of their homologous sides, also of their altitudes, and the segments of their bases; they are, therefore, as the squares of the sides, altitudes, and homologous segments of the bases.

In every parallelogram, the sum of the squares of the two diagonals is equal to the sum of the squares of the four sides: and the two diagonals bisect each other.

This proposition M. de Lagny takes to be one of the most important in all geometry; he even ranks it with the celebrated forty-seventh of Euclid, and with that of the similitude of triangles; and adds, that the whole first book of Euclid is only a particular case of it. For if the parallelogram be rectangular, it follows, that the two diagonals are equal; and, of consequence, the square of a diagonal, or, which comes to the same thing, the square of the hypothenuse of a right angle is equal to the squares of the sides.

If the parallelogram be not rectangular, and, of consequence, the two diagonals be not equal, which is the most general case, the proposition becomes of vast extent; it may serve, for instance, in the whole theory of compound motions, &c.

There are three ways of demonstrating this proposition; the first by trigonometry, which requires twenty-one operations; the second geometrical and analytical, which requires fifteen. But M. De Lagny gives a more concise one, in the *Memoires de l' Acad.*, which only requires seven.

PARALLELOGRAM, *See* PENTAGRAPH.

PARAMETER (from the Greek παρα, *through*, and μετρεω, *to measure*) in conic sections, a constant right line in each of the three sections; called also *latus rectum*. In the parabola, the rectangle of the parameter and an abscissa are equal to the square of the correspondent semi-ordinate. *See* PARABOLA.

In an ellipsis and hyperbola, the parameter is a third proportional to a conjugate and transverse axis. *See* ELLIPSIS and HYPERBOLA.

PARAPET, (French) or BREASTWORK, in fortification, a defence or screen, on the extreme of a rampart, or other work, serving to cover the soldiers and the cannon from the enemy's fire.

The thickness of the parapet should be about eighteen or twenty feet, in order to be cannon-proof, and it should be about seven or eight feet high, when the enemy has no command above the battery; otherwise it should be raised high enough to cover the men while they load the guns. Its length depends on the number of guns to be employed in the battery: for one gun, it is common to allow eight yards in length, and six yards more for every other gun. The parapet consists of two parts; the wall contained in one piece from end to end, and about two and half or three feet high; and the merions, which are detached pieces of the parapet, leaving openings, called embrasures, through which the cannon deliver their shot.

The parapet of the wall is sometimes of stone. The parapet of the trenches is either made of the earth dug up; or of gabions, fascines, barrels, sacks of earth, or the like.

PARAPET, is also a little wall, breast-high, raised on the brinks of bridges, quays, or high buildings; to serve as a stay, and prevent accidents from falling over.

In roof buildings, it assists in forming the gutter, and tends to resist the outward thrust of the roof by its weight or vertical pressure. It is worthy of remark, that in the late Gothic buildings, when the roofs were of a low pitch, and consequently had considerable lateral thrust, the walls were almost invariably terminated by a parapet.

PARASTATA, (Greek,) in ancient architecture, a kind of pier, or piedroit, serving as a defence or support to a column or arch.

Mr. Evelyn makes the parastata the same with pilaster; Barbaro and others, the same with antæ; and Daviler, the same with piedroit.

PARCLOSE, a screen frequently of open-work, employed in churches to separate chapels, tombs, and other portions of the church from the main body.

PARENT, ANTHONY, in biography, an eminent mathematician, born at Paris in the year 1666. At a very early period, he discovered a strong propensity to the study of mathematics; for, at the age of fourteen, accidentally meeting with a dodecahedron, upon every face of which was delineated a sundial, excepting the lowest, upon which it stood, he attempted to imitate them, and was led from the practice to investigate the theory, and in a short time wrote a treatise upon *Gnomonics*, which, though said to be extremely rude and unpolished, had the merit of being his own invention, as was a work on *Geometry*, which he wrote about the same time. At the earnest desire of his relations, he entered upon the study of the law, as a profession for his life; but he no

sooner completed his studies in that faculty, than he betook himself, with increased ardour, to those pursuits which accorded best with his genius and inclination. He attended, very diligently, the lectures of M. de la Hire and M. Sauveur, and, as soon as he felt himself capable of teaching others, he took pupils; and fortification being a branch of study which the war had brought into particular notice, he was called upon frequently to teach the principles of that science. In 1699, M. Fillau des Billets having been admitted a member of the Academy of Sciences at Paris, with the title of their academician, nominated M. Parent for his *élève*, who particularly excelled in that branch of knowledge. It was soon discovered that he directed his attention to all the subjects that came before the Academy, and that he was competent to the investigation of every topic which was recommended to their notice. In the year 1716, the king abolished the class of *élèves*, and on this occasion he made M. Parent an adjunct, or assistant member of the class of geometry. He lived but a short time to enjoy his honour, being in the same year cut off by the small-pox, when he was about fifty years of age. Although of a very irritable disposition, he is said to have possessed great goodness of heart; and though his means were extremely limited, he devoted much of his income to acts of benificence. He was author of *Elements of Mechanics and Natural Philosophy, Mathematical and Physical Researches*, a sort of journal, which first appeared in 1705, and which, in 1712, was greatly enlarged, and published in three vols., 4to.; and *A Treatise on Arithmetic*. Besides these, he wrote a great number of papers in the different French *Journals*, and in the volumes of the *Memoirs of the Academy of Sciences*, from the year 1700 to 1714, and he left behind him, in manuscript, many works of considerable research; among which were some complete treatises on divers branches of mathematics, and a work containing proofs of the divinity of Jesus Christ, in four parts.

PARGET, (from the Latin, *parces*, a wall,) in natural history, a name given to the several kinds of gypsum or plaster-stone, which, when slightly calcined, make what is called *plaster of Paris*, used in casting statues, in stuccoing floors and ceilings, &c.

The word *parget*, though generally applied to all the gypsums, is, however, given by the workmen principally to the two species which make up the first genus of that class, called by Dr. Hill the *pholides*. These are the Montmartre kind, and that of Derbyshire.

PARGETING, in building, a term used for the plastering of walls; sometimes for the plaster itself.

Pargeting is of various kinds; as, 1. White lime and hair mortar laid on bare walls. 2. On bare laths, as in partitioning and plain ceiling. 3. Rendering the insides of walls, or doubling partition walls. 4. Rough-casting on heart-laths. 5. Plastering on brickwork, with finishing mortar, in imitation of stone work; and the like upon heart-laths.

The term pargeting is also applied to the ornamental plaster-work common in timber houses of the Elizabethan period.

PARKER'S CEMENT. *See* CEMENT, MORTAR, &c.

PARLOUR, (French, *parler*, to speak,) a room for conversation. Primarily, the apartment in a nunnery where the nuns are permitted to meet and converse with friends and visitors; hence with us the parlour is the room in a house which the family usually occupy when there are no visitors, as distinguished from a drawing-room, for the reception of company, or from a dining-room, when a distinct apartment is allotted for that purpose. The term is likewise used to signify a room on the ground-floor, and a better sort of apartment in houses of entertainment.

PARQUETRY, inlaid work, the same as MARQUETRY, which see.

PARSONAGE, a house adjoining, or in proximity to a church, the residence of the officiating priest.

PARTHENON, one of the finest temples of ancient Athens, dedicated to Minerva. It was of the Doric order, erected by Ictinas in the palmy days of Greek art, the sculptor being Phidias. It is situated about the middle of the citidal, and is built altogether of admirable white marble; the plan of it is above twice as long as it is broad, being 217 feet 9 inches long, and 98 feet 6 inches broad. It has an ascent on all sides of five steps. The peristyle consists of 46 pillars of the Doric order, chennelled, 8 whereof are distributed at each end of 17 on either side; they are 42 feet high, and 17½ feet in circumference, the intercolumns measuring 7 feet four inches.

The following particulars are extracted from Stuart:—

"Within the peristyle, at either end, there was an interior range of 6 columns of 5½ feet in diameter, forming a vestibule to the door of the cella or *adytum*, these vestibules were ascended by two steps from the peristyle.

"The cella, 62½ feet broad within, was divided into two unequal chambers, of which one was nearly 44 feet long, and the other about 97½ feet long. The ceilings of the smaller chamber was supported by 4 columns, and of the larger by 16 columns; the order of these interior columns is unknown, as all traces of their ornaments appear to have perished; even their existence can be but conjectured by means of the construction of the pavement, and by a trace of *one* of the columns in either chamber.

"The existence of these internal columns is not, however, admitted by Wilkins, who made a very minute inspection of the building in 1801. The metopes were enriched with sculptures executed in high relief; the subject a series of combats between one of the Lapithæ and the Centaurs; in the tympan of the pediments, were sculptured groups of a colossal size, many of the figures being perfect *statues, wholly detached from the tympanum, and sculptured all round.* The circumstances attending the birth of Minerva, were represented over the one entrance, and also the contest between the goddess and Neptune for the *honour* of presiding over the affairs of the city; for the Athenians, in choosing a tutelary diety, did not omit the opportunity of paying a compliment to their national vanity. Behind the columns of both fronts, was another range of columns of lesser dimensions, advanced before the antæ of the pronaos and pasticum, contrary to the usual Greek practice, as the area of the pronaos and of the pasticum was elevated two steps above the peristyle. The entablature or frieze of the inner range was continued along the side-walls of the temple, and enriched with sculptures executed in bas relief; it was not broken by the insertion of triglyphs, but in the epistylium, the guttæ or drapo are introduced in the same manner as when the usual insertion of triglyphs was made. This afforded an opportunity for an uninterrupted representation of the grand procession which took place at the celebration of the Panathenæan festival.

"The transverse walls terminating the pronaos and pasticum, receded 12 feet behind the columns of the interior ranges, and doorways of ample width and height were left in them for the approaches to the cella. Stuart imagined the Parthenon to have been of that description of temples called Hypæthral, or those of which the cella was divided into three aisles, of which the two next the side-walls were covered with a roof, and the middle aisle left open to the sky. The researches of recent travellers having thrown additional light on this subject, his opinion is no longer tenable, and

the passage in Vitruvius, which was considered to allude to this temple, has been shown to be a corruption of that author's text. There were no columns in the cella of the temple. The roof was unquestionably of timber, and covered with marble, sculptured so as to represent large tiles, after the mode observed in the temple of Jupiter at Olympia.

Some of the blocks of stone, of which the Parthenon is composed, are so closely fitted, that no separation is visible; and in some instances, where the adjoining fragments of two contiguous stones have broken off, they adhere almost as firmly as though they had never been disjoined; this cohesion is, however, only observable in the *vertical* joints, the separation between the horizontal beds of the blocks, is far more conspicuous. The want of cement was amply supplied by the liberal use of *iron cramps;* in a block of four feet in length, three cramps are sometimes found connecting it with the next adjoining. One set of cramps being used for connecting the stones of the same bed together, and the other for connecting the superincumbent courses; the first, which united both the end and at the sides, resembled the letter H, protracted so as to be from 11 to 15 inches in length. The others were plates of iron, 5 inches in depth, 3 in width, and $\frac{3}{4}$ of an inch thick. They are usually inserted half their depth into the stones beneath the vertical joints of the next superior course, the other remaining to be received into a groove made across the common joint of the two blocks meeting above it. Holes of the same form, but of greater dimensions, were sunk for the reception of the first sort of cramps, the space being filled around with melted lead; lead was also used in fixing the second sort of cramps in the horizontal courses, but no means appear to have been employed for its introduction at the angles of two blocks, whose vertical joint is immediately above them. The stones composing the shaft of each column, were held together by round pins of wood; *square* sockets of the same material were first sunk in the centre of two adjoining blocks, the socket of the lower course received half the pin, and the other half projected into the socket in the upper stone. The pins which have been found, appear to have shrunk very considerably; besides these, there were usually two metal plates of the kind already mentioned, inserted in those blocks composing the column, as in the other part of the building.

PARTITION, (from the Latin, *partitio*, to divide,) a wall which divides and separates one apartment from another. It may be either of brick, stone, or timber. When a partition wall has no support from below, it ought to be so constructed as to lay no stress upon the floor; and, therefore, a truss partition should be employed to discharge the weight. *See* Truss.

PARTY WALLS, in building, partitions of brick made between buildings in separate occupations, for preventing the spread of fire. For the regulations prescribed by act of Parliament, *see* House.

PARVIS, or Parvise, a name formerly given to the porch of a church, but now applied to the area round a church. Of late, it has been used to signify the room often found above the porch of a church. It is supposed to be a corruption of *paradise.*

PASCAL, BLAISE, a celebrated mathematician and philosopher, born at Clermont, in Auvergne, in the year 1623. His father, who was a man of great consideration in his province, was also illustrious as a general scholar, as well as an able mathematician. To promote the studies of his only son, Blaise, he relinquished his official situation, settled at Paris, and undertook the employment of being his tutor. The pupil was, from a very early period, remarkably inquisitive, and desirous of knowing the principles of things; and when good reasons were not given to him, he would search for better; nor would he rest contented with any that did not appear to his mind well founded. His father soon discovered that the bent of his genius was decidedly to mathematics, from which he was determined, if possible, to keep him, lest he should, by this pursuit, be prevented from learning the languages. He accordingly locked up all the books that treated of geometry and the sciences, properly so called, and refrained even from speaking of them in his presence. On one occasion, however, the youth asked, with an importunity not to be put off, what was geometry? to which the father replied, "geometry is a science which teaches the way of making exact figures, and of finding out the proportions between them;" but, at the same time, he forbade him to speak or think of the subject any more; which was, perhaps, the very readiest way to excite in him an earnest desire to become acquainted with it. Accordingly, the science soon occupied all his thoughts; and though but twelve years of age, he was found, in the hours of recreation, making figures on the chamber-floor, with charcoal, the proportions of which he sought out by means of a regular, though perhaps uncouth, series of definitions, axioms, and demonstrations. It is said, apparently upon unquestionable authority, that he had proceeded with his inquiries so far as to have come to what was just the same with the thirty-second proposition of the first book of Euclid, and that without any assistance either from living instructors or the works of the illustrious dead. From this time, young Pascal had full liberty to indulge his genius in mathematical pursuits, and was furnished by his father with Euclid's Elements, of which he made himself master in a very short time. So great was his proficiency in the sciences, that, at the age of sixteen, he wrote a *Treatise on Conic Sections*, which, in the judgment of the most learned men of the time, was considered as a great effort of genius. At the age of nineteen he contrived his admirable arithmetical machine, furnishing an easy and expeditious method of making arithmetical calculations, in the fundamental rules, without any other aid than that of the eye and the hand. About this time, owing to ill health, he was obliged to suspend his studies, which he was unable to renew for four years; when, having been witness to the famous Torricellian experiment respecting the weight of air, he instantly directed his attention to discoveries in the science of pneumatics. He made a vast number of experiments, of which he circulated a printed account through the whole of Europe. He soon ascertained the fact of the general pressure of the atmosphere, and composed a large treatise, in which he fully explained the subject, and answered the objections which were advanced against his theory: afterwards, thinking it too prolix, he divided it into two small treatises, one of which he entitled, *A Dissertation on the Equilibrium of Fluids;* and the other, *An Essay on the Weight of the Atmosphere.* These treatises were not published till after the author's death.

The high reputation which M. Pascal had acquired, caused him to be looked up to by the most considerable mathematicians and philosophers of the age, who applied for his assistance in the resolution of various difficult questions and problems. Among other subjects on which his ingenuity was employed, was the solution of a problem suggested by Mersenne, which had baffled the penetration of all who had attempted it; this was to determine the curve described in the air by the nail of a coach-wheel, while the machine was in motion; which curve was at that time known by the name of the *roullette*, but is now designated the *cycloid.*

Before this time he had drawn up a table of numbers, which, from the form in which the figures were disposed, he called his *Arithmetical Triangle.* He might perhaps have been an

inventor of it, but it is certain that it had been treated of, a century before Pascal's time, by Cardan, and other arithmetical writers.

When M. Pascal was in the twenty-fourth year of his age, and the highest expectations were formed of the advantages to be attained in science from his labours, he on a sudden renounced the study of mathematics, and all human learning; devoted himself wholly to a life of mortification and prayer; and became as great a devotee as almost any age has produced. He was not, however, so completely abstracted from the world, as to be wholly indifferent to what was passing in it; and in the disputes between the Jesuits and the Jansenists, he became a partisan of the latter, and wrote his celebrated *Provincial Letters*, published in 1656, under the name of Lewis de Montalte, in which he only employed his talents of wit and humour in ridiculing the former. These letters have been translated into almost all the European languages, and probably nothing did more injury to the cause of the Jesuits. The course of life which he prescribed to himself, proved unfavourable to his health of body and mind. His reason became in some measure affected, and in these circumstances, an accident produced on his mind an impression which could not be effaced. In 1654, while he was crossing the Seine in a coach-and-four, the two leading horses became unmanageable at a part of the bridge where the parapet was partly down, and plunged over the side into the river. Their weight fortunately broke the traces, by which means the other horses and the carriage were extricated on the bank of the precipice. In his then enfeebled state, this fright was too much for the unfortunate Pascal; and so serious were its effects on him, that he never afterwards had the possession of his mental faculties. He always imagined that he was on the edge of a vast abyss on the left side of him, and he would at no time sit down till a chair was placed there, to assure him there was no real danger. After languishing some years in this miserable state, he died at Paris in 1662, at the age of 39.

PASSAGES, the avenues or accesses which lead to the various apartments of a building.

Passages must always be convenient to give ready access, and proportional in width and height to the magnitude of the other apartments, and with suitable decorations.

PASTIL, or PASTEL, (from the Latin *pastillus*,) among painters, &c. a sort of paste, made of several colours ground up with gum-water, either together or separately, in order to make crayons, to paint with on paper or parchment.

PASTOPHORIA, (Greek) in antiquity, apartments near the temples, for lodging the pastophori, or priests, whose business it was, at solemn festivals, to carry the shrine of the deity.

Clemens Alexandrinus, describing the temples of the Egyptians, says, that "after having passed through magnificent courts, you are conducted to a temple, which is at the farther end of these courts, and when a pastophorus gravely lifts up the veil, which is the door, to show you the deity within, which is nothing but a dog or a cat, or some other animal." Apuleius speaks of the pastophori that carried the Syrian goddess.

In the temple of Jerusalem there were two courts surrounded with galleries, and round about were several lodging-rooms for the priests to lay up wood, wine, oil, salt, meal, spices, incense, vestments, valuable vessels, and provisions, necessary for the sacrifices and lamps, as also for the support and maintenance of the priests. *See* 1 Chron. ix. 26, 33; xxvi. 16. Ezek. xl. 17, 18.

PASTORAL-STAFF the official staff used by a bishop. *See* CROZIER.

PATE, in fortification, a kind of platform, like what they call a horse-shoe; not always regular, but generally oval, encompassed only with a parapet, and having nothing to flank it. It is usually erected in marshy grounds, to cover a gate of a town, or the like.

PATEN, a plate or salver employed in the eucharist.

PATERA, (from *pateo*, I am open,) among antiquaries, a goblet, or vessel, used by the Romans in their sacrifices, in which they received the blood of their victims, offered their consecrated meats to the gods, and made libations.

On medals, the patera is seen in the hands of several deities; and frequently in the hands of princes, to mark the sacerdotal authority joined with the imperial, &c. Hence F. Joubert observes, that besides the patera, there is frequently an altar, upon which the patera seems to be pouring its contents.

The patera is an ornament in architecture, frequently introduced in friezes, fascias, and imposts, over which are hung festoons of husks or flowers; or they are sometimes used by themselves, to ornament a space; and in this case it is common to hang a string of husks or drapery over them; sometimes they are much enriched with foliage, and have a mask or head in the centre.

In vol. xiv. of the Archæologia, a description and plate are given of a Roman patera and vase dug up when sinking a ditch in Essex, in June, 1800. They were found near an ancient Roman road, between Camelodunum and Camboritum. "The metal vase and patera merit attention, as none similar to the first have been figured or described in the works of the society; nor do I know that any like either have been presented for their inspection. The vase is of that form which Montfaucon has figured in his 2d. vol., pl. 19, fig. 10, and calls a *præfericulum*, used by the Romans at their sacrifices, for pouring wine into the patera. *See* p. 88, where he controverts Festus's opinion that the præfericula were without handles. Another, more nearly resembling that here represented, is given in his 3d. vol., pl. 24, fig. 9, and called by Beger an *epichysis*, but not allowed to be such by Montfaucon. The metal patera which belongs to the above, differs from the earthen pateræ in general, by being bossed in the centre, a circumstance not easily to be accounted for, unless it was for the firmer fixing the præfericulum upon, when placed with the body at the time of interment." With the above Roman antiquities were found several little cups of Samian ware. "The uses of these elegant little cups have not," the antiquary continues, "that I know of, been ascertained by any author. The real purposes to which they were applied must remain at present in obscurity."

It may be stated, also, that the Hindoos, in their sacrifices and ceremonies, have immemorially used, and still use, articles exactly similar to those described in vol. xiv. of the Archæologia, plates 1 and 5; and it is curious to see how nearly they agree in form. A comparison of the article in the plates just adverted to, with those in plates 83, 86, and 105 of the Hindoo Pantheon, will strikingly evince this. The *sacrificial vase*, in the latter plate, has the same form, though more elaborately ornamented, as the above described præfericulum; and the others exhibit metallic circular pateræ, and the central embossment, which, though "not easily accounted for," is found among Hindoo mystics to have very profound allusions. The Roman patera has also the mysterious rim, or *yoni*, respecting which the reader may consult the work last referred to. Dr. Clarke, in his Travels, notices that "the patera used by priestesses in the rites of Ceres, had this pyramidal node or cone in the centre. A priestess is represented holding one of these, on a bas-relief, in the vestibule of Cambridge University library." Vol. ii., p. 334. Greek

Marbles, No. xv., p. 37. Similar articles are still used in the rites of the Hindoo Ceres; as are also the "little cups" described and exhibited in the Archæologia, as above referred to, and in many of the plates of the Hindoo Pantheon. In India, they are used for holding clarified butter, a common ingredient in the frequent oblations to fire; and unguents, and holy water, in the *sradha*, or funeral obsequies, and in other rites and ceremonies.

PATERNOSTERS, in architecture, a sort of ornaments in form of beads, either round or oval, used on baguettes, astragals, &c.

PAVEMENT, (from the Latin *pavimentum*, derived from *pavire*, to make the earth firm and strong by beating,) a layer or stratum of stone, or other matter, serving to cover and strengthen the ground of divers places, for the more commodious walking on, or for the passage of carriages.

The paving of streets is one of the most beneficial regulations of police that have been transmitted to us from our ancestors. Several cities had paved streets before the commencement of the Christian era; nevertheless, those which are at present the ornament of Europe (Rome excepted) were destitute of this great advantage till almost the twelfth or thirteenth century. It is probable that those people who first carried on the greatest trade, were the first who paid attention to have good streets and highways, in order to facilitate that intercourse which is so necessary to keep up the spirit of commerce. Accordingly, we are told by Isidorus (*Origin.* lib. xv. cap. 16), that the Carthaginians had the first paved streets, and that their example was soon copied by the Romans. Long before that period, however, Semiramis paved highways, as appears by the vain-glorious inscription which she herself caused to be put up (Strabo, lib. 16. Diod. Sicul. lib. ii. v. 13. Polyæni, *Stratagem*, lib. viii. cap. 26.) The streets of Thebes, and probably those of Jerusalem, were paved; but neither the streets of Rome nor the roads around it were paved during the time of its kings. In the year U. C. 188, after the abolition of the monarchical form of government, Appius Claudius, being then censor, constructed the first real highway, called after him the *Appian Way*, and, on account of its excellence, the *queen of roads*. The time when the streets were first paved cannot be precisely ascertained; some have referred this improvement to the year 578, after the building of the city; others to 584; and others to 459; at which several periods some parts of the city and suburbs might have been paved. That streets paved with lava, having deep ruts made by the wheels of carriages, and raised banks on each side, for the accommodation of foot-passengers, were found both at Herculaneum and Pompeii, is well known.

Of modern cities, the oldest pavement is commonly ascribed to that of Paris; but it is certain that Cordova, in Spain, was paved so early as in the middle of the ninth century, or about A. D. 850. The capital of France was not paved in the twelfth century, but the orders for this purpose were issued by the government in the year 1184, on which occasion it is said that the name of Lutetia, deduced from its dirtiness, was changed into that of Paris. Nevertheless, in the year 1641, the streets in many quarters of Paris were not paved. That the streets of London were not paved at the end of the eleventh century is asserted by all historians. It does not appear when paving was first introduced; but it was gradually extended as trade and opulence increased. Several of the principal streets, such as Holborn, which are at present in the middle of the city, were paved for the first time by royal command, in the year 1417; others were paved under Henry VIII.; some in the suburbs in 1544: others in 1571 and 1605: and the great market of Smithfield in 1614.

In England, the pavements of the principal streets &c., are made of various descriptions of materials, according to the kind of stone most readily procured. In London, Aberdeen granite, broken-stone, &c. are used. Wood and asphalte have also been used to a great extent. Courts, stables, kitchens, halls, churches, &c. are paved with tiles, bricks, flags, or fire-stone; sometimes with a kind of free-stone, and rag-stone.

In some cities, as at Venice, the streets, &c. are paved with brick; churches sometimes are paved with marble, and sometimes with mosaic work, as the Church of St. Mark, at Venice. In France, many of the public roads, streets, courts, &c., are paved with *gres*, or *grit*, a kind of free-stone.

In Amsterdam, and the chief cities of Holland, they call their brick pavement the *burgher-master's pavement*, to distinguish it from the stone or flint pavement, which usually takes up the middle of the street, and which serves for carriages; that which borders it being for the passage of people on foot.

The several kinds of pavement are as various as the materials of which they are composed, and whence they derive the name by which they are distinguished; as,

1. *Pebble-paving*, which is done with stones collected from the sea-beach, mostly brought from the islands of Guernsey and Jersey; they are very durable, indeed, the most so of any stone used for this purpose. They are used of various sizes, but those which are from six to nine inches deep are esteemed the most serviceable. When they are about three inches deep, they are denominated *bolders* or *bowlers;* these are used for paving court-yards, and other places not accustomed to receive carriages with heavy weights: when laid in geometrical figures, they have a very pleasing appearance.

2. *Rag paving* was formerly much used in London, but is very inferior to the pebbles; it is dug in the vicinity of Maidstone, in Kent, from whence it has the name of Kentish rag-stone; there are squared stones of this material for paving coach-tracks and foot-ways.

3. *Purbeck pitchens;* squared stones used in foot-ways; they are brought from the island of Purbeck, and also frequently used in court-yards; they are in general from six to ten inches square, and about five inches deep.

4. *Squared paving*, for distinction by some called *Scotch paving*, because the first of the kind paved in the manner that has been, and continues to be paved, came from Scotland; the first was a clear close stone, called *blue wynn*, which is now disused, because it has been found inferior to others, since introduced, in the order they are hereafter placed.

5. *Granite of various kinds*, as:—

First—Guernsey Granite, a very close, hard, and durable stone, exceedingly well adapted for pavement, but subject to become polished, and consequently slippery. It is that kind of slipperiness which, for distinction sake, may be called *dry*, as if black-lead had been rubbed upon it.

Second—Heron Granite; not so fine in its grain as Guernsey, but very close, hard, and durable. Its defect is a tendency to become *greasily* slippery—a very dangerous quality as respects the foot-passengers.

Third—Mount Sorrel Stone. This stone is pronounced by mineralogists to be not a Granite, but a Sienite. It is extremely close, hard, and durable, and it has the rare quality of neither becoming dryly nor greasily slippery. It has all the very best qualifications of good paving-stone, but (and it is a drawback of some importance) its intense hardness makes it brittle under the hammer when being re-dressed.

Fourth—Aberdeen Granite. That which is commonly

termed the Old Blue Aberdeen, is a very fine stone, not so dark in colour, more brilliant in appearance, almost as close in texture, and equally durable, under wear, as the best Guernsey stone; but there is sometimes a difficulty in obtaining an ample supply for the London market. The Granites from Aberdeen vary much in colour and in texture even in the same paving-stone, one end being often much inferior to the other.

Fifth—The Tyar Baggar Stone, also from Aberdeen, is redder in colour, and, although beautifully brilliant and close, and apparently hard, is decidedly inferior in durability to the Old Blue Aberdeen.

Sixth—The Foggintor Devonshire Granite is not, in its appearance, equal to Aberdeen, but there is an equality and toughness in its composition, which, as far as experience of it has gone, leads us to consider it durable and serviceable.

Seventh—The Haytor Devonshire Granite, perhaps from greater inequality of texture, has not proved so durable.

Eighth—The White Rock, a Cornish Granite, has worn exceedingly well in some streets of London.

The Cornish Granites are, however, generally too soft for use as paving-stones.

All these stones are less slippery than Guernsey or Herm-stone.

Ninth—The Budle Stone, from Northumberland, and the best of the Red and the Blue Scotch whinstones, scarcely now make their appearance. They are very good stones.

An extremely dark-green Whinstone, from near Queensferry, has been manufactured into curbstone and paving-stone, but it is decidedly too soft for use, for either purpose. Various kinds of limestone, or coarse marble, and ragstones and pebbles, are used in provincial places, as they formerly were in the streets of London; they are not now sent to the metropolis in any quantity.

6. *Purbeck paving*, for footways, is, in general, got in large surfaces, about two inches and a half thick; the blue sort is the hardest and the best of this kind of paving.

7. *Yorkshire paving* is an exceedingly good material for the same purpose, and is got of almost any dimensions, of the same thickness as the Purbeck; this stone will not admit the wet to pass through it, nor is it affected by the frost.

8. *Ryegate*, or *fire-stone paving*, is used for hearths, stoves, ovens, and such places as are liable to great heat, which does not affect this stone, if kept dry.

9. *Newcastle flags*, are stones about two feet square, and one and a half or two inches thick; they answer very well for paving out-offices; they are somewhat like the Yorkshire.

10. *Portland paving*, with stone from the island of Portland; this is sometimes ornamented with black marble dots.

11. *Sweedland paving*, is a black slate, dug in Leicestershire, and looks well for paving halls, or in party-coloured paving.

12. *Marble paving*, is mostly variegated with different marbles, sometimes inlaid in mosaic.

13. *Flat brick paving*, done with brick laid in sand, mortar, or grout, as when liquid lime is poured into the joints.

14. *Brick-on-edge paving*, done with bricks laid edgewise in the same manner.

15. Bricks are also laid flat or edgewise in herring-bone.

16. Bricks are also sometimes set endwise in sand, mortar, or grout.

17. Paving is also performed with paving-bricks.

18. With ten-inch tiles.

19. With foot tiles.

20. With clinkers, for stables and out-offices.

21. With the bones of animals, for gardens, &c. And,

22. We have nob-paving, with large gravel-stones, for porticoes, garden-seats, &c.

By most writers, common stone pavements are divided into two classes: *rubble* causeway, in which the stones are of irregular shape, and very imperfectly dressed with the hammer; and *aisler* causeway, which is formed of stones of larger size accurately squared and dressed. In both kinds the excellence of the pavement depends greatly on the firmness and evenness of the bed, and the careful fitting of the stones to each other, which may be accomplished with very irregular stones by judicious selection. If one stone be left a little higher or lower than those adjoining it, or if it become so in consequence of defective building, the jolting of carriages in passing over the defective place, will quickly damage the pavement; the wheels acting like a rammer in driving the depressed stones deeper into the earth, while the derangement of the lateral support that each stone should receive from those adjoining it, occasions the dislocation of the pavement to a considerable distance, and the consequent working up of the earth through the disturbed joints. Defective joints form another fruitful source of injury and inconvenience both to the pavement itself and the vehicles jolted over it. If, as is often the case in inferior pavements, the edges of two adjoining stones do not meet with accuracy, narrow wheels will have a tendency to slip into the joint, and by doing so, to wear the edges of the stones, till, as may be frequently seen, the surface of each stone is worn into a convex that renders the footing of horses insecure, and causes the motion of vehicles drawn rapidly over them to consist of a series of bounds or leaps from one stone to another, accompanied by a degree of lateral slipping highly injurious to the carriage, while the irregular percussion produced tends greatly to the destruction of the pavement.

The formation of the bed on which the stones are to rest is of great importance, and various substances, as sand, gravel, broken-stone, &c., have been used by paviours for this purpose; the general introduction of concrete, however, has removed the difficulty formerly experienced, as, by means of this valuable composition, a firm, hard, and dry foundation is easily obtained.

The bed of the pavement should be laid with concrete.

For paving stones, hard rectangular blocks of granite are preferred, though whinstone, limestone, and even free-stone, may be used. Guernsey granite, as we have shown, appears to be the most durable, but it is more liable to become inconveniently smooth than some stones of inferior hardness. The stones may vary according to the traffic, from 6 to 10 inches deep, 6 to 18 inches long, and 4 to 18 inches wide; but it is very essential that the depth of all the blocks in one piece of pavement should be alike, and that where the width is unequal, the stones may be so sorted that all used in one course are uniform in this particular. The accurate dressing of the stones is a point often too little attended to; and an injudicious mode of forming contracts for paving, in which the payment has been by the square yard of paving laid, has, in connection with the effect of competition in bringing prices below the remunerating point, led to the use of stones in which the base is smaller than the upper surface, and which, when laid, scarcely come in contact with each other except at their upper edges. In some pavements the stones are made smaller at the top than at the bottom, the joints being filled up with stone-chips, concrete, or an asphaltic composition; and in those of the more common construction, the sides of

the stones are occasionally hollowed, so as to receive a small quantity of gravel or mortar, which serves as a kind of dowelling. Ramming the stones with a heavy wooden rammer is a practice that has been much recommended, and it is considered that a more efficient application of the process, by means of a ramming machine, or *portable monkey*, would remove some of the defects arising from imperfect bedding; but when the stones are well laid, and bedded in strong mortar, as the best recent pavements are, a few blows with a wooden maul, of about fourteen pounds weight, are sufficient to fix them firmly in their place. Grouting with lime-water, poured all over the pavement, facilitates the binding of the whole together, and fills up the joints, so as effectually to prevent the working up of the substratum. The blocks are commonly laid in rows across the road, the joints in each row being different from those of the adjoining ones; but pavements of superior smoothness have been laid in courses stretching diagonally across the street, by which means all the joints are passed over by carriages with greater ease. This arrangement is particularly desirable at the intersection of streets, as it diminishes the risk of horses slipping. Longitudinal courses are objectionable, on account of the tendency of narrow wheels to enter the joints. In paving steep inclinations, it is well to use narrow stones, on account of the number of cross joints; or if large stones be used, to cut deep furrows across their surface, to afford secure footing.

The enormous expense of maintaining some of the great metropolitan thoroughfares, led to the introduction of various plans for paving with wood, asphalte, and other materials. Of these, with the exception of wood, little need be said, as a very short trial of any of them proved that they were not suited to bear the wear of London traffic. Wood-pavement, however, has been tried on so large a scale, and though not equal to broken granite, or a well-paved road, for durability, has yet so many advantages, that some account of it seems necessary. The most primitive descriptionof a wooden road, perhaps, is that known in America by the name of *corduroy road*, consisting of rough logs of timber laid close together across the track, but the wooden pavement, properly so called, seems to have been first used in Russia, and tried on a limited scale at Vienna, New York, and some other places. One of the earliest kind used consisted of blocks of fir or other wood cut in hexagonal cylinders of six or eight inches diameter, and from eight to twelve or fifteen inches deep, and placed close together, with the grain vertically. Such a pavement is smooth when first laid, but, unless the foundation be very carefully prepared, it is liable to sink into hollows like the common stone-pavement, owing to the want of cohesion between the individual blocks, a deficiency which it has been proposed to remedy by pegging or dowelling the pieces together, though their form is not very suitable for the purpose. Of the numerous other plans of wood-paving proposed, but one has been tried on an extensive scale, that of the Metropolitan Patent Wood-Paving Company. The mode of paving by this Company was invented by the Count de Lisle. In this the blocks are sawn into a rhomboidal shape, the upper surface forming an angle of about 65° with the direction of the grain, by which the durability of an end-section is in a great degree preserved, while the inclination of the sides causes each block to receive support from those adjoining it, and affords facilities for pinning the whole paving together by pegs. One course, or transverse row of blocks being laid so that they all incline in one direction, each block has on one side two projecting pegs, and on the other, two holes. The adjoining course is laid in like manner, but sloping in the opposite direction. By this disposition the two pegs on one side of a block enter two distinct blocks in the adjoining row, while the holes on the other side receive in like manner the pegs of two other blocks, so that each block is pinned to four others, besides receiving support from the adjoining blocks of its own course. Where this principle of construction is fully carried out, the whole pavement of a street becomes, as it were, one mass, being so pinned together that no block could be raised without breaking the dowels; but as it is necessary sometimes to disturb the pavement in order to get at the gas and water pipes, the practice of this Company has been to lay down the wood in masses of twenty-four or thirty-six blocks, so united by iron cramps that the blocks, thus connected together, may be laid down and taken up when necessary, at once. This sort of pavement is always laid on a well-formed foundation of concrete, about six inches deep.

Wood-pavement has been laid, to a great extent, in the principal thoroughfares of London, and in many provincial towns. Its undeniable advantages were its smoothness when first laid, producing great ease of draught, quietness, and cleanliness, but, on the other hand, its slipperiness rendered it, in some states of the weather, extremely dangerous to horses. Besides this objection, unless kept in a very high state of repair, it became rough and uneven, and if so kept, its expense was quite equal to a good broken-stone road, and much more so than a well-paved granite road.

The advocates of wood-pavement, however, have been obliged to abandon, in a great measure, its use for the public streets, and from these it is gradually disappearing, though it is still retained, and extensively used, for stables, warehouses, railway stations, &c.; in such places it answers exceedingly well, and is, perhaps, the best description of paving that can be adopted.

Foot-pavements of flag-stones require very little remark. The curb-stones should be very hard, and firmly set in cement, or in a bed of gravel or concrete. They should be set from four to six inches above the surface of the carriage-way, which may be made to abut immediately upon them without the intervention of a gutter. Where gutters are introduced, cast iron ones have sometimes been used; but in our opinion, dressed granite stone channels are to be preferred. The flag-stones, which should never be less than two inches and a half thick, are commonly bedded in mortar in a layer of gravel; but sometimes, when there are no cellars underneath, are laid dry. A slight degree of slope should be given to the pavement, to conduct water to the gutters, for which purpose a fall of one inch in ten feet is sufficient, while a steep inclination is objectionable from its danger in slippery weather. The best material for foot-pavements is Yorkshire stone.

Among the substitutes for common flagstones that have been recommended, may be mentioned slate, which appears to be very durable. Some pavements or floors of this material have been laid at the London Docks, where, among other advantages, it is found preferable to wood in point of cleanliness. Tramways of slate two inches thick are found strong enough to bear waggons or carts with four or five tons of goods; and some are laid, of only half that thickness, on an old wooden floor.

Several descriptions of asphalte have also been used for footways with various success. The best is that known as Claridge's Asphalte of Syssel; this answered extremely well, though not equal to Yorkshire stone. It has been used extensively for footways in railway stations and similar situations, for which it is well adapted.

PAVEMENT OF TERRACE, that which serves for covering in manner of a platform; whether it be over a vault or a wooden floor. Those over vaults are usually of stones

squared and bedded in lead. Those on wood, called by the Latins, *pavimentum contignata*, are either stones with beds for bridges, tiles for ceiling of rooms, or lays of mortar made of cement and lime, with flints or bricks laid flat, as is still practised by eastern and southern nations on the tops of houses. All those pavements which lie open, were called by the Latins, *pavimenta subdialia*.

Pavement, Diamond, those pavements of which the stones, flags, or bricks, are laid with their diagonals parallel and perpendicular to the sides of the apartment.

PAVILION, (French, from the Italian, *padiglione*, *a tent;* derived from the Latin, *papilio*) in architecture, a kind of turret, or building usually insulated, and contained under a single roof; sometimes square, and sometimes in form of a dome; and thus called from the resemblance of its roof to a tent.

Pavilions are sometimes also projecting parts, in the front of a building, marking their middle. Sometimes the pavilion flanks a corner, in which case it is called *an angular pavilion*. The Louvre is flanked with four pavilions. They are usually higher than the rest of the building.

There are pavilions built in gardens, popularly called *summer-houses*, *pleasure-houses*, &c. Some castles or forts consist only of a single pavilion.

PAUTRE, ANTONY LE, in biography, an eminent French architect, born at Paris in 1614, who distinguished himself by his taste in the decoration of buildings. Several edifices from his designs were erected in the capital and its neighbourhood, of which the most noted were the wings of St. Cloud, the church of the nunnery of Port-Royal, and the hotels of Gevres and Beauvais. He was appointed architect to the king's brother, and afterwards to the king himself. He was a member of the Academy of Architecture from its first institution, and published a work on that art, intitled *Les Œuvres d'Architecture d'Antoine le Pautre*, of which the first edition appeared in 1652. He died in 1691. His son Peter was eminent as a sculptor.

PAX, a small tablet, generally of metal, with a handle used for the *osculum pacis*, or kiss of peace.

PEDESTAL, (from the Latin, *pes*, *pedis*, *foot*, and στυλος, *column*) in architecture, the lowest part of an order of columns; being that which sustains the column, and serves it as a foot to stand on.

The pedestal, called by the Greeks *stylobates*, and *stereobates*, consists of three principal parts: viz., a square trunk, or dye, which makes the body; a cornice, the head; and a base, the foot of the pedestal.

The pedestal is properly an appendage to a column; not an essential part thereof; though M. Le Clerc thinks it is essential to a complete order.

The proportions or ornaments of the pedestal are different in the different orders: Vignola, indeed, and most of the moderns, make the pedestal, and its ornaments, in all the orders, one-third of the height of the column, including the base and capital: but some deviate from this rule.

M. Perrault makes the proportion of the three constituent parts of pedestals the same in all the orders, viz., the base one-fourth of the pedestal; the cornice an eighth part; and the socle, or plinth, of the base, two-thirds of the base itself. The height of the dye is what remains of the whole height of the pedestal.

Pedestal, Tuscan, is the simplest and the lowest of all. Palladio and Scamozzi make it three modules high; Vignola five. Its members, in Vignola, are only a plinth, for a base; the dye; and a talon crowned, for a cornice. This has rarely any base.

Pedestal, Doric, Palladio makes four modules five minutes high; and Vignola, five modules four minutes.

In the antique, we not only do not meet with any ped but even not with any base, in the Doric order.

The members in Vignola's Doric pedestal are the same with those in the Tuscan, with the addition of a mouchette in its cornice.

Pedestal, Ionic, in Vignola and Serlio, is six modules high; in Scamozzi five; in the temple of Fortuna Virilis it is seven modules twelve minutes. Its members and ornaments are mostly the same with those of the Doric, only a little richer. The pedestal now usually followed, is that of Vitruvius, though we do not find it in any work of the antique. Some, in lieu hereof, use the attic base, in imitation of the ancient.

Pedestal, Corinthian, is the richest and most delicate of all. In Vignola it is seven modules high; in Palladio five modules one minute; in Serlio six modules fifteen minutes; in the Coliseum, four modules two minutes.

Its members, in Vignola, are as follow: in the base are a plinth for a socle, over that a tore carved, then a reglet, a gula inverted and enriched, and an astragal. In the dye are a reglet, with a conge over it; and near the cornice a reglet, with a conge underneath. In the cornice is an astragal, a frieze, fillet, astragal, gorge, and a talon. See each under its proper article.

Pedestal, Composite, in Vignola, is of the same height with the Corinthian, viz. seven modules; in Scamozzi six modules two minutes, in Palladio six modules seven minutes, in the Goldsmiths' arch seven modules eight minutes.

Its members, in Vignola, are the same with those of the Corinthian; with this difference, that, whereas these are most of them enriched with carvings in the Corinthian, they are all plain in the Composite. Nor must it be omitted, that there is a difference in the profiles of the base and cornice, in the two orders.

The generality of architects, Daviler observes, use tables, or panels, either in relievo or creux, in the dyes of pedestals, without any regard to the character of the order. Those in relievo, he observes, only fit the Tuscan and Doric; the three others must be indented; but this, he adds, is a thing the ancients never practised, as being contrary to the rules of solidity and strength.

Pedestal, *Square*, that whose height and width are equal; as that of the arch of the lions at Verona, of the Corinthian order; and such some followers of Vitruvius, as Serlio, Philander, &c., have given to their Tuscan orders.

Pedestal, *Double*, that which supports two columns, and is larger in width than height.

Pedestal, *Continued*, that which supports a row of columns without any break or interruption; such is that which sustains the fluted Ionic columns of the palace of the Tuileries, on the side of the garden.

Pedestals or Statues, are those serving to support figures or statues.

Vignola observes there is no part of architecture more arbitrary, and in which more liberty may be taken, than in the pedestals of statues; there being no laws prescribed for them by antiquity, nor any even settled by the moderns.

There is no settled proportion for these pedestals; but the height depends on the situation, and the figure they sustain. Yet, when on the ground, the pedestal is usually two-thirds, or two-fifths, of that of the statue; but always the more massive the statue, the stronger must be the pedestal. Their form, character, &c., are to be extraordinary and ingenious, far from the regularity and simplicity of the pedestals of columns. The same author gives a great variety of forms—oval, triangular, multangular, &c.

PEDIMENT, in architecture, a kind of low pinnacle, serving to crown porticos, or finish a frontispiece; and placed as an ornament over gates, doors, windows, niches, altars, &c.

The pinnacles of the ancient houses, Vitruvius observes, gave architects the first idea of this noble part; which still retains the appearance of its original.

The parts of the pediment are, the tympanum and its cornice. The first is the panel, naked, or area of the pediment, enclosed between the cornice, which crowns it, and the entablature, which serves as a base, or socle.

Architects have taken a great deal of liberty in the form of this member; nor do they vary less as to the proportion of the pediment. The most beautiful, according to Daviler, is that where its height is about one-fifth of the length of its base. The pediment is usually triangular, and sometimes an equilateral triangle; this is also called a *pointed pediment.* Sometimes it is circular; though Pelibien observes, that we have no instances of round pediments in the antique, beside those in the chapels of the Rotunda. Sometimes its upper cornice is divided into three or four sides, or right lines; sometimes the cornice is cut, or open at top, which is an abuse introduced by the moderns, particularly by Michael Angelo. For the design of this part, at least over doors, windows, &c., being chiefly for the purpose of sheltering those underneath from the rain, to leave it open in the middle is evidently to frustrate its end.

Sometimes the pediment is formed of a couple of scrolls or wreaths, like two consoles joined together. *See* CONSOLE.

Sometimes, again, the pediment is without base, or its lower cornice is cut out, all but what is bestowed on two columns, or pilasters, and on these an arch or sweep, raised in lieu of an entablature; of which Serlio gives an instance in the antique, in a Corinthian gate at Foligny, in Umbria; and Daviler, a more modern one, in the church of St. Peter at Rome.

Under this kind of pediments, also come those little arched cornices, which form pediments over doors and windows, supported by two consoles, in lieu either of entablature or columns.

Sometimes the pediment is made double, *i. e.* a less pediment is made in the tympanum of the larger, on account of some projecture in the middle; as in the frontispiece of the church of the great Jesus, at Rome: but this repetition is an abuse in architecture, though authorized by some very good buildings; as may be seen in the large pavilion of the Louvre, where the Caryatides support three pediments, one in another.

Sometimes the tympanum of the pediment is cut out, or left open, to let in light; as we see under the portico of the Capitol, at Rome.

In all the remains of Grecian architecture, the horizontal cornice is never interrupted or broken, nor is there any instance of a circular pediment, nor of any open at the top. The proportion of the tympanum is from one-fifth to one-ninth part of the span, in the pediments which remain of Grecian edifices. In the Doric tetrastyle portico at Athens, the height of the tympanum is about one-seventh part of its triangular base. The portico of the temple of Theseus is hexastyle; and the height of the tympanum of the pediment is about an eighth part of the span of its triangular base. The portico of the temple of Minerva is octostyle; and the height of the triangular tympanum, about one-ninth of its base. So that the higher the pediment, the less is the height in proportion. And thus the pediments of doors and windows ought to be still higher, as is verified in the frontispiece of the entrance-door of the Tower of the Winds, at Athens, where the height of the tympanum is only one-fifth part of the triangular base.

Vitruvius expressly disapproves of the use of dentils, modillions, or mutules, in pediments, for this reason; that as mutules and modillions were the representations of rafters, and dentils the representations of laths, and as these essential parts were always placed in the inclined sides of the roof from the ridge, to overhang the eves, it would certainly have been improper to use mutules, modillions, or dentils, in a situation where the originals themselves never existed.

Arches under pediments, is an abuse in architecture.

PELASGIAN, or CYCLOPEAN ARCHITECTURE. These titles are applied indiscriminately to a class of ancient buildings, to be found in various parts of Greece, which consist principally of walls and fortifications, such as the walls surrounding their acropoles. They are of colossal dimensions, and composed of immense stones, or rather masses of rock, from which circumstance they have obtained the title of Cyclopean, as also because structures of a similar description have been attributed to the labours of the Cyclopes by many of the Greek historians. The erections it is certain are of very early date, and are in all probability of Pelasgic origin, though whether the Pelasgi and Cyclopes are of the same race or not, it would be difficult if not impossible to decide. The Pelasgi, it is well known, were settled in Greece at a very early period, and were spread over the greater part of the country, until the arrival of the Hellenes: it is also very probable that they had emigrated originally from Asia across the Hellespont, and round the northern shores of the Ægean sea. It is true that this is somewhat opposed to the Greek traditions, which make the Peloponnesus the original seat of the Pelasgi; but this is probably but a national boast, and may be classed in the same category as the Athenian claim to the title of *αυτοκθενες*. This matter, however, as well as the whole of the early history of Greece, is involved in great obscurity, and has been the subject of much learned controversy, into which it is not our intention to enter in this place, nor is it at all requisite to the due consideration of the matter before us. There is also a striking similarity in the construction of these edifices, and of those described under CELTIC ARCHITECTURE; but here again it is next to impossible to tell what connection existed between the builders of Stonehenge and those of Argos or Mycenæ, although this circumstance, as well as others, would lead us to suppose that they had a common origin. The investigation of such subjects are interesting, but are attended with great uncertainty. We shall hereafter have occasion to call attention to a particular instance of the similarity existing between buildings of the two classes, which is very remarkable; one of the structures existing in Ireland, the other at Mycenæ.

The Pelasgian buildings are remarkable chiefly, as we have before stated, for the rudeness of their construction, and the enormous dimensions of the stones of which they are composed; indeed, they are little better than piles of rock heaped together, and sustained in their places by their own gravity, without the assistance of any cementitious preparation. Mr. Hamilton divides the existing remains into four classes, the earliest and most rude being that in which vast masses of rock were piled one upon the other in the same state as they came to hand, without any squaring or other adaptation for the position they were to occupy. In such masonry, there must have been, of course, apertures of considerable size left between the separate masses, and these were filled up with smaller stones, so as to render the work solid and compact. Of the larger stones, some of the masses are of such vast dimensions, as to contain as much as 216 cubic feet. Of this

description are the walls of Tiryns and Mycenæ, although the latter are probably of more recent date than the former, the sides of the stones being somewhat adapted to each other.

In the second method, the stones are somewhat smaller, and are of irregular size and figure, the different stones varying from each other in both respects; but the surfaces of each are adapted to the others with great nicety. It would seem as if the stones, when taken from the quarry, were worked according to the shape in which they happened to be detached from their beds, by reducing the sides to an even surface, but still preserving the general form of the mass. These polygonal stones were generally of seven or eight sides, but sometimes of as many as thirteen; they form a wall of considerable stability and strength.

In the third mode, the stones were laid in horizontal courses, but were of different dimensions, one stone occasionally rising above the level of the adjoining ones, so that the courses were somewhat irregular; the joints, too, were sometimes perpendicular, but at others inclined to the horizon at various angles.

The fourth method comprises walls composed of stones squared on all sides, and of the form of parallelopipedons, layed in regular horizontal courses. In all these methods, the stones were layed dry without any mortar, and yet they are so strong as to have resisted the vicissitudes of three thousand years. Sometimes we find more than one method adopted in the same structure, but this is probably owing to more recent additions or repairs.

Amongst the more noted examples of this mode of building, stand the walls of Tiryns and Mycenæ, and the treasury of Atreus, which we proceed to describe *seriatim;* but we must premise, that we are indebted for the descriptions to the accounts of Stuart and Hughes.

The ruins of Tiryns are probably the oldest and best examples now in existence, and are supposed to have been erected about fourteen centuries B. C. This acropolis is built on a small mount about 50 feet above the level of the plain, and the foundations of the enclosure are still perfect. It had entrances from the east and west, and one at the south-eastern angle. That at the east is still in tolerable preservation, and is approached by an incline, 15 feet wide, along the eastern and southern sides of a tower 20 feet square, and 40 feet high, passing at the end of the second side under a gateway composed of immense blocks of stone; the stone forming the architrave being 10½ feet long. It is thought that there was formerly a triangular stone above the architrave of this portal, forming a kind of pediment; the fragments are now lying on the spot, but without any appearance of having been sculptured. The walls are generally 25 feet thick, and are formed of three parallel ranks of stones, five feet thick, which separate two ranges of galleries in the walls, each five feet broad, and about twelve feet high; the sides of the galleries are formed of two courses of stone, and the covering of other two horizontal courses, which project until they meet.

The roof is pointed when seen from below, the lower surfaces of the stones being cut at an angle of 45 degrees. That part of the gallery which is now uncovered, is about 90 feet long, and has six openings or recesses towards the east, one of which is a kind of window or door, which probably communicated with some exterior building, of which there are still some traces of the foundation in existence; the space between these niches varies from 10 feet 6 inches to 9 feet 8 inches, and the niches themselves are from 5 feet 6 inches to 4 feet 10 inches wide. These galleries probably continued all round the citadel; but they are only accessible at present where the walls are least perfect, at the southern part of the enclosure. They were probably constructed for shelter of the garrison in case of siege, as no loopholes or other apertures open from them into the plain, which would have been the case had they been constructed for any defensive purpose. If the inner gallery received light from the arched area, the exterior must have remained almost dark.

No remains of the south-eastern portal remain: it appears to have been connected with the eastern gate by an avenue enclosed between the outer wall and the inner curtain, yet it is not easy to conjecture the use of this singular place. Others of a similar kind are met with at Argos, and in some other ancient cities of Greece.

The northern point of the hill is less elevated than any other, and its wall is composed of stones of a smaller size than those employed in the galleries. All the exterior walls are composed of rough stones, some of them 9 feet 4 inches in length, and 4 feet thick—their usual size is from 3 to 7 feet. The wall, when entire, must have been about 60 feet high. On the eastern side, the wall has been entirely destroyed, probably by the Argives, about 460 years before Christ, that the city might be left entirely unprotected.

There is a small entrance-gate, in the *pointed* form, 6 feet 1 inch wide, situated in the recess of the western wall; it is defended by a wall projecting in a curve.

The whole length of the citadel is about 660 feet, and the breadth about 180 feet; and the walls are constructed upon a straight line, without any reference to the sinuosities of the rock.

"The Propylæa, or massive portal of the Acropolis of Mycenæ, is one of the most interesting antiquities which time has spared. It is of Cyclopean architecture, constructed with blocks of surprising magnitude, the architrave consisting of a single stone, 15 feet in length, by 4½ in height: two parallel walls, composed of huge masses, piled up in an uncouth manner, which nothing but their size and weight would ever have kept firm, project from the gateway, and form an oblong court about 50 feet deep." "Over the architrave of this portal is one of the most ancient pieces of sculpture existing perhaps in the world; it is cut in high relief upon a triangular stone, the base of which is 11 feet, and the perpendicular height 10, being very similar in appearance to an armorial shield. The subject is an inverted column resting upon a portion of its entablature, between two lions rampant for supporters; each animal stands on a columnar plinth, at equal distances from the pillar, whose inverted pedestal is decorated with a kind of beaded string, consisting of four spherical balls; there is also seen on the frieze of the entablature immediately under the capital of the column, an elliptical excavation, and half the same device appears under each of the plinths on which the lions stand."

To the south of the gate of the lions, the wall of the capital is much ruined. In one part something like a tower is visible, which being perpendicular, while the curtain inclines a little inward from its base, there remained a projection at the top sufficient for an archer to defend the wall below. The blocks of the superstructure are in general of large dimensions, while those of the foundation are considerably smaller.

With the exception of the gates, the whole circuit of the citadel is constructed of rough masses of rock, very accurately adjusted and fitted to each other, though the smaller stones which filled up the interstices have generally disappeared: this style of building has commonly been called Cyclopean. It certainly appears that the walls of the most ancient cities of the Peloponnesus, whether attributed to

the Cyclops or not, were of this construction. Tiryns and Mycenæ differ from other acropoles in their galleries and gates, so that perhaps the ponderous method which so nearly resembles the style used by the Egyptians, of which the gate of the lions is the best specimen in Europe, is the real Cyclopean; while the remainder of the circuit is the work of the natives. These fortifications were reputed to be impregnable, and were so in ancient times. At the siege of Mycenæ by the Argives, these warriors found themselves unable to destroy the city, but they forced the inhabitants to surrender through famine. Mycenæ was demolished by the Argives at the time of the destruction of Tiryns; the buildings were overthrown, and the city for nearly 3,000 years has been desolate.

The southern ramparts of the citadel and all the other walls follow the natural irregularity of the precipice on which they are founded. At its eastern point it is attached by a narrow isthmus to the mountain. It is a long, irregular triangle, standing nearly east and west; the walls are mostly constructed of the second style of well-jointed polygons, although the rough construction is occasionally seen.

So small a fortress seems unworthy of the Tirynthian hero; but though the space it occupies is so circumscribed, the walls are truly herculean; their general thickness is 21 feet, in some places they are 25; their present height, in the most perfect part, is 43 feet. In some places there are square projections from the walls, in form of towers; but the projection is very slight: the most perfect of these is at the south-east angle, its breadth is 33 feet, and its height 43 feet.

The construction of the lateral walls is nearly regular, differing from the walls which constitute the peribolus, or boundary, of the acropolis, which are irregular polygons; they are of the hard breccia stone found on the spot, but the block ornamented with the lions resembles in its appearance the green basalt of Egypt. The back or inner part of the gate of the lions is highly interesting, as it exhibits two styles of construction totally differing from each other; that side which is towards the plain of Argos is of the rough Cyclopean masonry, while the other side is regularly constructed like the front of the gate and two lateral walls which diverge from it. It would appear that the gate had been made some time after the original Cyclopean structure. Without presuming to decide whether the regular as well as the irregular or polygonal construction were not sometimes employed at the same period, there are indeed reasons for believing, that while the walls of acropoles, or citadels, and other strong places, were composed of Cyclopean masonry, the temples, sepulchres, and sacred edifices were formed of a more regular construction; as the former were principally adapted to resist the impulse of warlike engines, while the sanctuaries of the gods, and the chambers of the dead, were regarded with reverential awe even by enemies.

A magnificent wall, composed of irregular polygons, closely united and carefully smoothed, supports the terrace on which the gate of the lions is situated.

The area of the acropolis is a long irregular triangle, standing nearly east and west. On the northern side, the declivity also is very steep, and there is a gate which consists of two stones, covered by a third. The opening is 5 feet 11 inches wide at bottom, and 5 feet 4 inches at top. Above the architrave is a large stone approaching the form of a triangle, with which the ruin is about 14 feet high. The gates folded, and were secured by bars. The access to this entrance was by an artificial terrace, which was completely commanded by the wall. A curtain nearly in a right line extends from this gate to that of the lions; and it is very probable that certain holes in the earth above this wall, which are shown by the natives as cisterns, are actually connected with galleries similar to those of Tirynthus. After entering the gate, there was a road, commanded by a wall, which traversed the hill almost to the opposite side before it turned to the summit; so that the acropolis was defended by at least a triple enclosure: on the northern side is a small gate, with its lintel, entire. The structure is so disposed, that those who entered it would have their left arm, which was guarded by the shield, on the side of the acropolis, which is a deviation from the common rule followed in constructing ancient Greek fortresses of all ages. The grooves for the bolts in the jambs of the door are of large dimensions. A deep rocky glen separates the acropolis from the neighbouring hill: there was anciently a bridge over the ravine: one of the side-walls still remains, consisting in well-jointed polygons.

Of the treasury at Atreus, near Mycenæ, which is a very remarkable building, Mr. Hughes gives us the following description, which we would beg the reader to compare with the account of a structure at New Grange, near Drogheda, Ireland, given under Celtic Architecture. It is the opinion of many archæologists that the Titan Celtæ were of the same race as the Cyclops, who built the acropolis of Tiryns.

"Descending down a slope flanked by enormous walls, we arrived at a plain entrance, noble in its simplicity and magnitude; it is 10 feet in breadth by 18 in depth—one of the stones composing the architrave or lintel being a single block, 27 feet long, 16 broad, and 4 deep. Immediately over it is a triangular aperture, which probably contained sculpture appertaining to Egyptian rites; the pyramidal form of the triangle being considered an emblem of the fiery element. The chief apartment of this treasury is a dome, very similar in shape to an English bee-hive, constructed, like the galleries of Tiryns, with large blocks in horizontal courses, each course projecting over the one immediately below it, whilst the interior surface is cut into form by the chisel. The diameter of its area is 47 feet; and at the end of the first quadrant, to the right of the entrance, is a passage leading into an inner room, about 27 feet by 20 in dimensions, the walls of which are not lined with any kind of masonry. This vault, near 50 feet high, is finished at the top by a single stone, like the treasury of Minyas, at Orchomenos; however, it is not a key-stone, for the principle of the arch is unapplied to this peculiar mode of construction. The inner surfaces of the blocks are pierced with holes, from whence many bronze nails have been extracted, which are supposed, not without probability, to have fastened plates of that metal over the interior surface of the edifice, as at the Pantheon, Rome."

The approach to the treasury is 20 feet in width. The blocks of stone composing the larger chamber are laid in regular courses, of which there are thirty-four visible, each course being about two feet in thickness. The stones, however, are not all of equal dimensions, but are united with the greatest precision, and without the aid of cement; they are composed of the hard and beautiful breccia of which the neighbouring rocks almost entirely consist. The entrance to the inner chamber is 9½ feet high, 4 feet 7 inches wide at the base, and 4 feet 3 inches at top: it has also a triangular cavity above, similar to that over the larger chamber. These triangular spaces have been thought by some to be a rude method of relieving the centre of the lintel stone, and throw the weight upon its ends; but others suppose them to have some mystical allusion, which is not improbable.

Various other examples besides those just described still

remain in various parts of Greece, in Bœotia, Attica, Argolis. and Phocis; also at Julis and Delphi; but the above will probably give a sufficiently explicit idea of their general character.

PELECOIDES, (from the Greek πελεκυς, *a hatchet*, and ειδος, *form*) a figure in the form of a hatchet. Such is the figure B C D A, contained under the inverted quadrantal arcs A B and A D, and the semicircle B C D.

The area of the pelecoides is demonstrated to be equal to the square A C; and that, again, to the rectangle E B. It is equal to the square A C, because it wants, of the square on the left hand, the two segments A B, and A D, which are equal to the two segments B C and C D, by which it exceeds on the right hand.

PEND, a vaulted roof without groining.

PENDENT, or Philosophical Bridge, a wooden bridge supported by posts and pillars, and sustained only by buttments at the ends. *See* Bridge.

Pendent, an ornament not uncommon in the vaulted roofs of the late or perpendicular period of Gothic architecture. It consists of a boss of foliage, or other ornament, suspended from the summit of the vaulting at the end of ribs, which, converging from the soffit of the roof, meet at a point below, which is covered with the boss alluded to. Beautiful examples exist at Henry VII.'s chapel, Westminster.

Ornaments of a similar description occur also in the timber roofs of the same date, as likewise attached to the ends of the hammer-beams, or to the extremities of the ridge-pieces of a roof, to receive the ends of the barge-boards.

PENDENTIVE, in architecture, the whole body of a vault, suspended out of the perpendicular of the walls, and bearing against the arc-boutants.

Daviler defines it a portion of a vault between the arches of a dome, usually enriched with sculpture. Felibien, the plain of the vault contained between the double arches, the forming arches, and the ogives.

The pendentives are usually of brick, or soft stone; and care must be taken that the joints of the masonry be always laid level, and in right lines proceeding from the sweep whence the rise is taken.

The joints, too, must be made as small as possible, to save the necessity of filling them up with slips of wood, or of using much mortar.

Pendentive Bracketing, a cove bracketing, springing from the rectangular walls of an apartment upwards to the ceiling, so as to form the horizontal part of the ceiling into a complete circle, or ellipsis.

The proper criterion for such bracketing is, that if the walls are cut by horizontal planes through the coved parts, all the sections through such parts will be portions of circles, or portions of ellipses, having their axes proportional to the sides of the apartment, so that each section will be a compound figure. Besides having four curvilinear parts, it will have four other parts, which are portions of the sides of the rectangular apartment; and the axis of the ellipsis will bisect each side of the rectangle.

Pendentive Cradling. The surface to be formed may be thus conceived. Let a square be inscribed within the circumference of the base of a hemisphere, and let the hemisphere be cut by four planes through the sides of the square, perpendicular to the plane of the base; then let this hemisphere be again cut by another plane parallel to the plane of the base, to touch the section of the four parts cut off; the surface of the remaining solid will then consist of a portion of the hemisphere, one entire circle, and four equal semicircles, each at right angles to the entire great circle. Therefore, if the ribs be fixed in planes passing through the axis of the sphere, and the two ribs, which stand upon the diagonals, will be entire semicircles; or, if a dome be perforated by a cylindric surface, of which the axis is that of the dome, the ribs will still have the same position at any springing, which is one of the semicircular arches.

Plate I. *Figure* 1.—The representation of the pendentive cradling of a dome. No. 1, A B C D, the plan; B F C the springing-line of a semicircular form, described on the diameter, B C. The shaded parts, at *i*, *k*, *l*, *m*, *n*, mark the places for the feet of the ribs to stand upon. G, H, sections of the curb, No. 2. The elevation, O P and Q R, the shortest ribs used; of these, there are four each, standing in the middle.

Figure 2. No. 1, 2.—Plan and elevation, representing the pendentive cradling of a dome.

Figure 3.—The geometrical construction of the pendentive cradling of a segment dome. This figure shows the portions of the ribs that must be used in the construction of the carpentry: thus, C *u*, C *v*, C *w*, C *x*, are the ribs which every eighth-part of the plan requires.

Figure 4. No. 1, 2.—The plan and elevation of the pendentive cradling of a cone.

Plate 2. *Figure* 1.—Plans, sections, and ribs of pendentive cradling.

To construct this cradling, let A B C D, No. 1, be the plan, which is an oblong figure. We must find the circumscribing plan of the spheroid, so that the length and breadth shall be in the same ratio as the two dimensions of the plan. For this purpose, draw the diagonals, A C and B D, cutting each other in E. Through the centre E, draw M I parallel to B C, or A D, cutting the plan at X and H; also, through E draw K L, parallel to B A, or C D, cutting the side B C, at F. From the centre, E, describe a quadrant, to touch the side of the plan at F, so that the portion of the circumference may be contained between K E and I E; bisect the arc, and through the point of bisection, draw a line parallel to B C, or any of its parallels, cutting the diagonal, A C, in G; join F G and G H, and draw C K and C I respectively parallel to G F and G H; make E L equal to E K, and E M equal to E I; then about the two axes, M I and K I, describe an ellipsis, which will be the base of the spheroid that will form the surface for the ribs.

When the plane of th figure to be covered is square, draw the seats of the ribs as in preceding examples. Also, draw the kirb for the skylight in the same proportion as the sides of the plan: then the rib which stands upon F U will be the portion of the quadrant of a circle, described with the radius E K, as at No. 4, where *e k*, No. 4, answers to E K, No. 1; *k f* to K F; and *f u* to F U; then, by drawing the perpendicular, *f l* and *u n*, No. 4, to cut the quadrant, *k m*, at *l* and *n*, *l n* will show the portion of the curve which will form the complete edge of the rib to cover the part F U.

Take half the transverse axis, M E, No. 1, and apply it in the straight line, *m e*, the left-hand figure at the bottom; draw *e o* perpendicular to *m e*, and make *e o* equal E K, No. 1; describe the quadrant of an ellipsis, *o n l m*; make *m x*, *x w*, respectively, equal to M X, X W, No. 1, draw the perpendiculars, *w n* and *x l*, then the portion of the ellipsis, intersected at *n* and *l*, will be the edge of the rib to cover X W on the plan.

In like manner *b n*, No. 5, is the edge of the ribs to cover the half of either diagonal, A C or B D.

No. 2, the transverse section and elevation.

No. 3, the longitudinal section and elevation, showing how the ribs are to be fixed.

PENETRALE, the most sacred chamber of a heathen temple.

PENETRALIA, chapels in Roman houses, in which the females or household gods were placed.

PENITENTIARY HOUSE. *See* PRISON.

PENSTOCK, in engineering, a gate employed for ponding back-water; it works up vertically in a grooved frame.

PENTADORON, a Roman brick, whose length measures five palms. *See* BRICK.

PENTAGON (from the Greek πενταγονος, *quinquangulus*, compounded of πεντε, *five*, and γωνια, *an angle*) in geometry, a figure of five sides and five angles.

If the five sides are equal, the angles are so too; and the figure is called a *regular pentagon*. Most citadels are regular pentagons.

The most considerable property of a pentagon is, that one of its sides, for example, D E, is equal in power to the sides of a hexagon and a decagon inscribed in the same circle, A B C D E; that is, the square of the side D E is equal to the sum of the squares of the sides D *a* and D *b*.

A pentagon, and also a decagon, may be inscribed in a circle, by drawing the two diameters, A P, *m n*, perpendicular to each other, and bisecting the radius *o n* at *q*. With the centre *q*, and distance *q* A, describe the arc A *r*; and with the centre A, and radius A *r*, describe the arc *r* B; then A B is one-fifth of the circumference; and A B, carried five times over, will form the pentagon; and the arc A B bisected in *s*, will give A *s*, the tenth-part of the circumference, or the side of the decagon.

If tangents be drawn through the angular points, they will form the circumscribing pentagon, or decagon. *See* POLYGON, and REGULAR FIGURE.

Pappus has also demonstrated, that twelve regular pentagons contain more than twenty triangles inscribed in the same circle, lib. v. probl. 45.

The dodecahedron, which is the fourth regular body, consists of twelve pentagons.

PENTAGRAPH, or more correctly PANTAGRAPH, or PARALLELOGRAM, an instrument for copying plans, maps, designs, &c., with expedition, even by a person unskilled in the art of drawing.

This instrument consists of four brass or wooden rulers, in the form of a parallelogram, with moveable joints at the angles; two of the rulers are extended beyond the parallelogram, one for the purpose of carrying a fixed socket, called C, with a metal tracer, in order to trace over the outlines of the original drawing or print; and the other, called B, for carrying a moveable socket; also called B, with a pencil, in order to trace out a drawing similar to the original. The parts, B and C, of the rulers thus extended, being upon the same side of one of the diagonals, the side of the parallelogram, called D, which adjoins the ruler with the moveable socket, has another moveable socket, also called D, in order to insert a vertical pin, which is fixed in a flat piece of lead; both of the moveable sockets, B and D, are clamped by means of a screw. As the metal tracer, C, the pin in the socket D, and the pencil in the socket B, are cylindrical, in fixing the instrument, the axes of the three cylinders must be set all in the same plane, and they will remain so throughout every movement of the instrument.

The pins which fasten the parallelogram at the angles being also vertical cylinders to the plane of the instrument, the axis of the metal tracing point, in the socket C, and those of the two pins in the sockets of B and D, must be in the same plane; also, the axis of the pin, in the socket D, and those of the ruler D at the joints, must also be in a plane. In order to make the movement of the instrument easy, it is provided with casters, or rollers, each of which turns on an axis in the same line with the axis at the joints or angles.

The extended part of the ruler B, on which the socket and pencil are carried, has several graduations, or divisions, which show the proportion of the drawing to be made to the original; and thus calling the centre of the joint connecting the extended bars, the *apex of the instrument*, the first division on the extended part, B, is equally distant from the apex with the axis of the tracing point on the other extended part, C; and the ruler, D, which has the steel pin, has a corresponding division, exactly opposite the vertex, when the extended rulers, B and C, are brought into a straight line, and, consequently, the instrument is divided thereby into two equal parts; and thus it becomes necessary to have the two opposite sides of the parallelogram, which has the side marked D, longer than the other two sides, one of which has the extended part B.

The divisions upon the extended part, B, being fixed upon, and numbered from 1-1, 1-2, 1-3, 1-4, to 1-12; that is, 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, &c., towards the vertex, the other divisions upon the side of the parallelogram, D, are marked with corresponding figures, 1-1, 1-2, 1-3, &c., in such a manner, that when the extended sides are brought into a straight line, the division marked 1-2, on the side D, divides the instrument into three equal parts, from the division 1-2 on B, to the point C, on the axis of the tracing point on the other extended leg, C; and thus the distance from 1-2, on the side D, to 1-2 on the side B, will be half the distance between 1-2 on the side D and the point C, on the extended part C.

In like manner, the division marked 1-3, on the side D, divides the instrument into four equal parts, from 1-3 on B, to the tracer on C; and thus 1-3 on D will be distant from 1-3 on B, and one-third of the distance from 1-3 on D to the axis of the tracer on C.

The other proportions are found in a similar manner.

The fiducial edges of the clamps, which carry the socket for the steel pin, and the socket for holding the pencil, cross the rulers, to which they are attached, at right angles, and would, if produced, cut the axis of the cylindrical socket in each of the said rulers. The upper part of the cylindrical case, which holds the pencil, is provided with a cup, to contain shot, or a small weight, in order to make the pencil press sufficiently, so as to mark the paper. In order to prevent the pencil from tracing the same path it has already described, a silk thread, or catgut string, connected with the pencil, passes through an eye at the vertex, returns to the hand of the operator, and being drawn tight, raises the pencil from the paper.

To use the instrument, suppose the drawing required to be one-half of the original; set the fiducial edge of the clamp B upon 1-2 in the extended part B, and the fiducial edge of the clamp D, upon 1-2 of the ruler D; slide the socket D upon the pin fixed into the lead weight, then having adjusted the original drawing, or print, under the tracer, and the paper under the pencil, trace over all the lines of the original, and the pencil at the remote extremity will trace out a similar figure.

Again, let us take another example: suppose the drawing required to be one-third of the original; set the fiducial edge of the clamp B upon 1-3 in the extended part B, and the fiducial edge of the clamp D upon 1-3 of the ruler D; slide the socket D upon the pin fixed into the leaden weight, then proceed as before. In the same manner the drawing may be reduced to $\frac{1}{4}$, $\frac{1}{5}$, &c. of the lineal dimensions, as shown by the graduations: but if any intermediate proportion is required, as between a third and a fourth; bring the fiducial edge of the clamp B to the intermediate point, and the fiducial edge of the clamp D in a straight line, then proceed as above. On the contrary, should it be required to enlarge the drawing, it is only necessary to change the pencil in the socket or tube of the clamp B, for that of the metal tracer, and the paper for the original, and proceed as before.

PENTASTYLE, (from πεντε, *five*, and στυλος, *a column*) in architecture, a work containing five rows of columns.

The portico begun by the emperor Gallienus, and which was to have been continued from the Flaminian-gate to the bridge Milvius, *i. e.* from the Porto del Popolo to the Porte Mole, was a pentastyle.

PENT-HOUSE, an open shed or projection placed over a door, window, clock, statue, &c., to project them from the weather.

PENT-ROOF, a roof consisting of two equally inclined sides meeting in a common apex, the former being that of a triangular prism.

PERAMBULATOR, (from the Latin, *perambulo*, to travel) an instrument for the measuring of distances, and in frequent use for measuring distances on roads, for settling disputes concerning the charges of the drivers of hackney-carriages, and for other purposes. It consists principally of a wheel, upon which it runs, and an index which shows the number of turns of such wheel, reduced into miles, furlongs, poles, and yards.

The carriage or stock is made of wood, and is about 3 feet long. At one end is a handle for the person who uses it, and the other is furnished with sockets in which the axle of the wheel turns; this end of the stock has the centre part removed, by which are left two arms between which the wheel works. Upon the stock, and just in front of the handle, is the dial-plate, with its two hands by which the distance is registered. The wheel is 8 feet 3 inches, or $\frac{1}{2}$ pole in circumference. Upon one end of the axis of this wheel is a small pinion, which works into a smaller pinion at the end of a rod, which passes up the stock or carriage to the works beneath the dial-plate. Motion is communicated by means of this rod to a worm or micrometer screw, which turns once round for each revolution of the carriage-wheel of the perambulator. This worm works into a wheel of 80 teeth, which is moved forward one tooth for every $\frac{1}{2}$ pole, and carries a hand or index, which makes one revolution for 40 poles or one furlong. On the axis of this wheel, is a pinion of 8 teeth, which works into a wheel of 40 teeth, and on the axis of this second wheel is a pinion of 10 teeth, which moves a wheel of 160 teeth. This last wheel carries another hand, which makes one revolution for 80 of the former. These hands are arranged in the same manner as the hour and minute hand of a watch, so that the three circles on the dial-plate are all concentric. The first of these circles is divided into 220, and the second into 40, the number of yards and poles contained in a furlong; the figures in these circles are read off by the first mentioned index, that which is attached to the wheel of 80 teeth. The third circle is divided into 80, the number of furlongs in 10 miles, and to this circle belongs the index attached to the wheel of 160 teeth. The distance is ascertained by reading off the figures in the reverse order in which the circles are given above; divide the number on the first circle by 8, and you will have the distance required in miles, furlongs, poles, and yards. The instrument is furnished with a stop or strap, so that after the distance is measured, the perambulator may be conveyed without the index being altered.

Unlike the pedometer, it requires no regulating, and the only risk of its giving the distance incorrectly, if well constructed, is passing over rugged and uneven roads, which will of course cause the index to show more than the true distance. In general, however, for short distances, this error is very trifling.

When about to commence a measurement, the wheel should be turned round until the first mentioned index points to 220 on the circle of yards. Some are provided with a click and racket, by which this may be done with much less trouble than by the wheel.

There are other instruments for the same or similar purposes, bearing different names, as *waywiser* and *odometer*, but the construction of all of them is very similar.

Waywiser is the name generally given to that form of the instrument which is applied to a carriage, in which, by a slight adaptation to one of the wheels of the carriage, the instrument is made to register the number of turns of such wheel, in the same manner as the perambulator.

PERCH, in land-measure, the 40th part of a square rood, containing $30\frac{1}{4}$ square yards; also used as a measure of length, being equal to $5\frac{1}{2}$ yards, or $16\frac{1}{2}$ feet, called otherwise a rod or pole.

PERCH, a bracket or corbel, a small projecting beam near the altar of a church.

PERCLOSE. *See* PARCLOSE.

PERIBOLUS, the enclosure surrounding a Grecian temple, which frequently contained a grove, and was adorned with altars, statues, &c.

PERIDROME, PERIDROMUS, in ancient architecture, the space, or an aisle in a periptere, between the columns and the wall.

Salmasius observes, that the peridromes served for walks among the Greeks.

PERIMETER, (from the Greek περι, *about*, and περιφερω, *measure*) in geometry, the ambit or extent that bounds a figure or body.

The perimeters of surfaces, or figures, are lines; those of bodies are surfaces.

In circular figures, &c., instead of perimeter, we say *circumference*, or *periphery*.

PERIPHERY, (from the Greek περιφερω, *I surround*, or περι, *about*, and φερω, *I bear*, or *carry*) in geometry, the circumference or bounding line of a circle, ellipsis, parabola, or other regular curvilinear figure.

The periphery of every circle is supposed to be divided into three hundred and sixty degrees; which are again subdivided, each into sixty minutes, the minutes into seconds, &c.

The division of degrees, therefore, are fractions, whose denominators proceed in a sexigesimal ratio; as the minute $\frac{1}{60}$, second $\frac{1}{3600}$, third $\frac{1}{216000}$. *See* SEXIGESIMAL.

But these denominators being troublesome, in their stead are used the indices of their logarithms; hence the degree, being the integer, or unit, is marked by °, the minute by ′, second by ″, &c. *See* CIRCLE.

PERIPTERE, (from the Greek περιπτερος, formed of περι, *about*, and πτερων, *wing*, winged on every side) in ancient architecture, a building encompassed on the outside with a series of insulated columns, forming a kind of aisle, or portico, all round. Such were the basilica of Antonine, the septizon of Severus, the portico of Pompey, &c.

Peripteres were properly temples with columns on all the four sides, by which they were distinguished from prostyles and amphiprostyles, the one of which had no columns before, and the other none on the sides.

M. Perrault observes, that periptere, in its general sense, includes all the species of temples which have porticos of columns all round, whether the column be diptere, or pseudodiptere, or simple periptere; which is a species that bears the name of the genus, and has its columns distant from the wall by the breadth of an intercolumniation. For the difference between periptere and peristyle. *See* PERISTYLE.

PERIPTERAL, surrounded by a periptere or continuous colonnade; the term is applied to a class of temples which answers to this description.

PERIRRANTERION, (from the Greek *περι*, *about*, and *ραινω*, *to sprinkle*,) lustral vases placed at the entrances of heathen temples, in which the priests washed their hands, and with which they sprinkled their worshippers.

PERISTYLE, (from the Greek *περιστυλος*, formed from *περι*, *about*, and *στυλος*, *column*,) in ancient architecture, a place or building, encompassed with a row of columns on the inside; by which it is distinguished from the periptere, where the columns are disposed on the outside. Such was the hypæthral temple of Vitruvius, and such are now some basilicas in Rome, several places in Italy, and most cloisters of religious houses.

Peristyle is also used by modern writers for a range of columns, either within or without a building: thus we say, the Corinthian peristyle of the portal of the Louvre, &c.

PERISTYLION, (from the Greek *περιστυλιον*,) among the Athenians, a large square place, though sometimes oblong, in the middle of the gymnasium, designed for walking, and the performance of those exercises which were not peculiar to the palæstra.

PERISTYLIUM, a continued row or series of rows of columns all round a court or building, in contradistinction to porticos, in which the pillars do not surround a space, but are arranged in one or more parallel lines.

PERITHERIDES, the same as Ancones.

PERITROCHIUM, (from *περι*, *about*, and *τροκιλος*, *a circle*,) in mechanics, a wheel, or circle, concentric with the base of a cylinder, and moveable together with it, about an axis. The axis, with the wheel and levers fixed in it, to move it, constitutes that mechanical power called *axis in peritrochio*.

PERPENDICULAR, (from the Latin *perpendicularis*,) in geometry, a line falling directly on another line, so as to make equal angles on each side; called also a *normal line*.

From the very notion of a perpendicular, it follows:—

1. That the perpendicularity is mutual; *i. e.*, if a line, as I G, be perpendicular to another, K H; that other is also perpendicular to the first.

2. That only one perpendicular can be drawn from one point in the same plane.

3. That if a perpendicular be continued through the line to which it was drawn perpendicular, the continuation will also be perpendicular to it.

4. That if there be two points of a right line, each of which is at an equal perpendicular distance from two points of another right line, the two lines are parallel to each other.

5. That two right lines perpendicular to one and the same line, are parallel to each other.

6. That a line, which is perpendicular to another, is also perpendicular to all the parallels of the other.

7. That perpendiculars to one of two parallel lines, terminated by those lines, are equal to each other.

8. That a perpendicular line is the shortest of all those which can be drawn from the same point to the same right line.

Hence the distance of a point from a line, is a right line drawn from the point perpendicular to the line or plane; and hence the altitude of a figure is a perpendicular let fall from the vertex to the base.

Perpendiculars are best described in practice by means of a square; one of whose legs is applied along that line, to or from which the perpendicular is to be let fall or raised.

A line is said to be perpendicular to a plane, when it is perpendicular to all right lines, that can be drawn in that plane, from the point on which it insists.

A plane is said to be perpendicular to another plane, when all right lines drawn in the one, perpendicular to the common section, are perpendicular to the other.

If a right line be perpendicular to two other right lines, intersecting each other at the common section, it will be perpendicular to the plane passing by those two lines.

Two right lines perpendicular to the same plane are parallel to each other.

If, of two parallel right lines, the one is perpendicular to any plane, the other must also be perpendicular to such plane.

If a right line be perpendicular to a plane, any plane passing by that line will be perpendicular to the same plane.

Planes, to which one and the same right line is perpendicular, are parallel to each other: hence all right lines perpendicular to one of two parallel planes, are also perpendicular to the other.

If two planes, cutting each other, be both perpendicular to a third plane, their common section will also be perpendicular to the same plane.

Perpendicular to a Curve, is a right line cutting the curve in the point in which any other right line touches it, and is also itself perpendicular to that tangent.

PERPENT-STONE, a long stone reaching right through a wall; a bond or thorough-stone.

PERPEYN-WALL, a projecting pier, buttress, or other support employed to sustain a beam or other weight.

PERRAULT, CLAUDE, an eminent architect, born at Paris in 1613. He was brought up to the medical profession, and took his degree as doctor of the faculty of Paris in 1641. He practised little, however, excepting among his friends and the poor; and having a decided taste for drawing and the fine arts, he turned his attention to the science of architecture, in which he became greatly distinguished. When the Academy of Sciences was founded, under the patronage of Colbert, in the year 1666, Perrault, who was one of the first members, was appointed to select a spot for an observatory; and he also gave a plan of the building which was to be executed. When it was resolved, under Louis XIV., to proceed in completing the palace of the Louvre, all the eminent architects were invited to give in designs of the façade; and that of Perrault was preferred. This is accounted the masterpiece of French architecture, and it would alone suffice to transmit his name with honour to posterity. It was in vain that persons, jealous of his reputation, endeavoured to make the public believe that the real designer was Le Veau; they entirely failed in their proof, and the glory of Perrault remained untarnished. When Colbert, after the king's first conquests, proposed to construct a grand triumphal arch to his honour, Perrault's design had the preference, and the edifice was commenced. It was, however, never finished. In its masonry, Perrault employed the practice of the ancients, of rubbing the surface of the stones together with grit and water, so as to make them cohere without mortar. Other works of this architect were, the chapel at Sceaux, that of Notre Dame, the church of the Petits Pères in Paris, the water-alley at Versailles, and most of the designs of the vases in the park of that palace. By the king's command, he undertook a translation of Vitruvius, with notes, published in 1673. All the designs for the plates of this work were drawn by himself, and have been esteemed as master-pieces of the kind. He afterwards published an abridgement of that author, for the use of students. He likewise facilitated the study of architecture by a work entitled *Ordonnance des Cinq Espèces de Colonnes selon la Méthode des Anciens*. In the preface to this work, he maintains that there is no natural foundation for the architectural proportions; but that they may be infinitely varied, according to taste and fancy—an

opinion which gave much offence, though justified by the practice of the ancients themselves. A collection of the drawings of several machines, which he at different times invented, was published after his death in 4to. This excellent artist holds a respectable place among writers in his original profession, and, besides various memoirs on this subject, communicated to the Academy of Sciences, he published *Memoirs pour servirà l' Histoire Naturelle des Animaux*, in 2 vols. His other writings of this class are contained in his *Essais de Physique*, 4 vols. One of these volumes relates entirely to the organ of hearing, under the title of *Traité de Bruit.* Another relates to the mechanism of animals, in which he anticipated Stahl in some of his opinions respecting the functions of the animal soul. In other parts of these essays, he treats on the peristaltic motion of the intestines,—on the senses,—on nutrition, &c. He died in Paris in 1688, aged 75.

Perrault published a *Dissertation upon the Music of the Ancients*, in 1680. He had, indeed, given his opinion upon the subject very freely, in the notes to his translation of Vitruvius, in 1673; where, in his commentary of the chapter upon *Harmonic Music according to the doctrine of Aristoxenus*, he declares that "there is nothing in Aristoxenus, who was the first that wrote upon concords and discords, nor in any of the Greek authors who wrote after him, that manifests the ancients to have had the least idea of the use of concords in music of many parts."

PERRON, (French), in architecture, a staircase lying open, or withoutside the building; properly the steps before the front of the building, leading into the first story, when raised to a little above the level of the ground. Perrons are of different forms and sizes, according to the space and height they are to lead to. Sometimes the steps are round, or oval; more usually they are square.

PERRONET, JOHN RODOLPHUS, director of the bridges and roads of France, born in 1708. He was brought up to the profession of architecture in the city of Paris, and made great progress in the art. In 1745, he became inspector of the school of engineers, of which he was afterwards a director. France is indebted to him for several of its finest bridges and best roads, the canal of Burgundy, and other great works. He was, for his public services, honoured with the order of St. Michael, and admitted a member of the Academy of Sciences at Paris, of the Royal Society of London, and of the Academy of Stockholm. He died at Paris in 1794. He wrote a *Description of the Bridges* which he had constructed, 2 vols. 12mo.; and *Memoirs on the Method of constructing Grand Arches of Stone from* 200 *to* 500 *Feet in span.*

PERSEPOLIS, a town of Persia, formerly called Elymaïs, now known only by its ruins and monuments, which have been described by many travellers, from Chardin to Niebuhr and Franklin. They are situated at the bottom of a mountain, fronting the south-west, about 40 miles to the north of Shirauz. They command a view of the extensive plain of Merdasht; and the mountain of Rehumut encircles them, in the form of an amphitheatre. Here are many inscriptions, in a character not yet explained; but which Niebuhr seems to have represented with great accuracy. The letters somewhat resemble nails, disposed in various directions, in which singularity they approach to what are called the *Helsing Runes* of Scandinavia, but the form and disposition seem more complex. Behind the ruin, to the north, is a curious apartment cut in the solid rock, and a subterraneous passage, apparently carried to a very considerable extent. Situated about three miles and a half to the north-east of these ruins is the tomb of Rustan, the ancient Persian hero. The temple, or palace, at Persepolis, now called *the throne of Jemshid*, is supposed to have been erected in the time of Jemshid, and to have been posterior to the reign of the Hindoo monarchs. The figures at Persepolis differ from those of Elephanta, which are manifestly Hindoo; and Sir William Jones conjectures that they are Sabian, which conjecture is confirmed by a circumstance, which he believes to have been a fact, *viz.*, that the *Takhti Jemshid* was erected after the time of Cayúmers, when the Brahmans had migrated from Irán, and when their intricate mythology had been superseded by the simpler adoration of the planets and of fire. Chardin, who observed the inscriptions on these ancient monuments on the spot, observes, that they bear no resemblance whatever to the letters used by the Guebres, in their copies of the Vendidád; whence Sir William Jones inferred that the Zend letters were a modern invention; and in an amicable debate with a friend named Bahman, that friend insisted that the letters, to which he had alluded, and which he had often seen, were monumental characters, never used in books, and intended either to conceal some religious mysteries from the vulgar, or to display the art of the sculptor, like the embellished Cúfick and Nágári on several Arabian and Indian monuments. *See* NEXT ARTICLE.

PERSIAN or PERSEPOLITAN ARCHITECTURE, is that style of building employed by the ancient Persians; it is called Persepolitan from Persepolis, the capital of Persia, where also are found the principal remains of this style. The Persian architecture bears some resemblance to that of India and Egypt in general character, but differs from it considerably in matters of detail. In all three places we meet with excavated tombs and sepulchral chambers hewn out of the perpendicular face of the rock; yet beyond the circumstance of their position and method of formation, we find little in common between those of Persepolis and the other countries: in the latter, the excavations are usually of very great extent, and consist of one or more passages leading into a large number of different apartments; whereas those of Persia are very shallow, and consist mainly of an architectural façade or portico, richly adorned with sculpture and other embellishments. Such are those at Naksh-i-Rustam; also the tomb of Darius, at the foot of Mount Rachmed, near the ancient Araxes. Another similarity is to be found in their massive proportions; and although in the works of Persia there is less real massiveness than in those of Egypt, yet the similarity of appearance points to a common origin. The pyramidal inclination of their walls is another indication of the same fact; and great resemblance in this point and in others may be observed in their porticos or propylæa, which, besides the pyramidal form of the erection, present us with the same description of entablature which, in the ruins of Persepolis as well as in those of Egypt, consist of a lofty crowning hollow or concave member, ornamented with vertical ribs or leaves, and in both cases terminated with a large fillet. The sculpture of the two countries is also of similar character, stiff and formal, and, together with the arrow-headed characters which are found equally in both styles, presents a very fair argument in favour of their relationship.

The principal ruins of this style, as we have before mentioned, are to be found in Persepolis, in the great plain of Merdasht or Istakhr; but others are also existing at Shapur, where they cover an area of six miles in circumference, amidst rocks and precipices, many of which are decorated with sculpture. At Moorghab, forty-nine miles north-east of Istakhr, are other extensive ruins, amongst which a ruin, called by the natives Musjed-i-Madre-Solyman, is remarkable, being considered by some as the tomb of Cyrus the

Great. Somewhat nearer to the ruins of Persepolis are the Naksh-i-Rejib, and the Naksh-i-Roostan, both of which are supposed to be the tombs of regal personages. The ruins of the neighbourhood of Firoze-abad are very extensive, occupying a space of about 17 miles by about half the distance: other ruins exist at Darabgherd, and many in other places, of some of which we shall attempt to give a short description, and as the ruins of Persepolis are amongst the most remarkable and better-known examples, we proceed with their description forthwith.

These ruins are situated in the plains of Merdasht, at the foot of the mountain of Kuliraj-met, and stand upon an elevated terrace or platform, formed by levelling the surface of the rock. The platform is in the shape of a parallelogram, but somewhat irregular in its outline, which follows the profile of the rock; its dimensions are on the south face 802 feet, on the north 926, and on the west 1,425. On each of these sides the terrace is elevated above the general surface of the surrounding country, but on the east side the mountain rises above it; the vertical height of the three sides varies from 14 to 40 feet, the faces being formed of gigantic square blocks of a dark-grey marble, beautifully polished, and fitted to each other with the greatest exactness without the aid of cement. The surface of the platform is not on the same level throughout, those parts which were covered with buildings being somewhat elevated above the rest. On the west side, which may be considered the principal one, and at a spot about midway between the centre and the north-west angle, is the approach, which consists of two flights of steps in contrary directions, which return again to the upper landing-place. The height of the platform at this place is about 20 feet, and the flight on the north side consists of 55, and that on the south of 53 steps, the risers measuring 4 inches, and the threads 14; the width of the flights is 25 feet 7 inches, and the distance between them at the base 42 feet. The steps are cut out of immense masses of solid marble, sufficiently large to compose from 10 to 14 steps. The half space at the top of the first flight is 51 feet 4 inches between the flights, and that at the top of the upper flight 75 feet; the upper flights are separated from the lower by a wall.

Having arrived at the top of these steps, the first thing which presents itself to your notice is a portal or propylon, standing at about 42 feet east of the steps. This lofty mass, which is similar in all respects to the propyla of Egypt, forms an entrance to the ruins, and consists of a pyramidal mass of masonry, diminishing upwards on all sides, and crowned by a cavetto, or hollow cornice, having a large aperture, which forms a doorway or entrance. The interior faces of this propylon are sculptured into the forms of two colossal bulls, which are elevated on a pedestal five feet above the level of the platform. At a considerable height above their backs are three small compartments filled with inscriptions in the arrow-headed characters. Passing forward through this portal still in an easterly direction, we find the ruins of a fine group of columns, at a distance of 24 feet from the portal; there were originally 4 columns, which were all erect in Chardin's time, but when Sir Robert Ker Porter visited the place, two of them only remained. They are the most perfect examples among the ruins, and were placed equidistant from each other, at a distance of 22 feet apart. Their bases are buried in the ruins; their capitals are singular and beautiful, consisting, as it were, of three combined in one. The shaft gradually narrows towards the top, varied by 39 flutings near the cincture, each of which is four inches in breadth; the total height of the columns is 54 feet. A space of 24 feet separates these columns from a second propylon, resembling the former both in shape and dimensions, except that its length is 18 feet instead of 21. The remains of the first portal are 39 feet high, and of the second 28 feet; the base of the piers is 5 feet 2 inches high, and projects inwards, and the bases upon which the figures stand are 1 foot 2 inches high. The second propylon is sculptured on the inner faces similarly to the first, but the animals represented have the body and legs of a bull, an enormous pair of wings projecting from the shoulders, and the heads looking to the east, showing the faces of men. On the head is a cylindrical diadem, on both sides of which horns are clearly represented winding from the brows upwards, to the front of the crown; the whole being surmounted with a sort of coronet, formed of a range of leaves like the lotus, and bound with a fillet beautifully carved in roses. At the distance of 52 feet south-eastward from the second portal is a water-trough, cut out of a single stone 20 feet long, and 17 feet 5 inches broad, and standing three feet high from the ground. From hence to the northern wall of the platform is covered with fragments, and the remains of one column not channelled as the others are, which is 12 feet 4 inches high.

The propyla, in all probability, lead to some main court or building of which there are no remains, for it would seem unreasonable to suppose that these portals formed only an entrance to the Palace of Forty Pillars as it is termed, and which now forms the principal mass of remains; this palace is to the south of the portals, which are placed east and west of each other, and east of the staircase, or approach from below, so that to a person approaching from that quarter the Palace of Forty Pillars would be invisible, and it would be necessary to turn to the right immediately after passing under the first propylon. Owing to these difficulties, it has been suggested that the principal ruins are not those of a palace, but of a temple, and that the palace was eastward of them. This conjecture is somewhat confirmed by the nature of the court, which from its remains would seem to be too crowded with columns for a hall of entertainment; and further, it is precisely similar in arrangement to the Egyptian temples. If such be the case, it must be supposed that the ruins of the buildings of which the propyla formed the entrance, have been removed from the north-east portion of the platform. Be this as it may, at the distance of 172 feet from the propyla, in a southward direction, is the approach to the court, which consists of a staircase of two flights, one west and the other east, giving access to the platform on which the court is erected. "On drawing near the Chehel-minar, or Palace of Forty Pillars," says Sir Robert Ker Porter, "the eye is riveted by the grandeur and beautiful decorations of the flight of steps which lead up to them. This superb approach consists of a double staircase, projecting considerably before the northern face of the terrace, the whole length of which is 212 feet; at each extremity, east and west, rises another range of steps, and again, about the middle, projecting from it 18 feet, appear two smaller flights rising from the same point. Here, the extent of the range, including a landing-place of 20 feet, amounts to 86 feet. The ascent, like that of the great entrance from the plain, is extremely gradual, each flight containing only 32 steps, none exceeding 4 inches in height, in breadth 14 inches, and in length 16 feet. The whole front of the advanced range is covered with sculpture. The eye at first roves over it, lost and bewildered by the multitude of figures." Amongst these sculptures, the figures of the bull and the lion, and representations of the flower of the lotus, repeatedly occur; some of the figures exceed the natural size. The wall occupied by these sculptures extends for a length of 98 feet, and the sculptures are arranged in three rows, one above the other; the faces of the inner terrace walls were also decorated with bas-reliefs. The staircase

itself is half-buried and the flights are of unequal height, the western consisting of 28 steps, and the eastern, where the ground is higher, of only 18.

On arriving at the top of this staircase, another large platform presents itself, paved with large blocks of stone, and covered with fragments of pillars; it is of large extent, stretching north and south 350 feet, and from east to west 380 feet. The distribution of the columns comprised four divisions, consisting of a central phalanx of six deep every way, an advance body of twelve in two ranks, and the same number similarly disposed flanking the central body. At the distance of 22 feet from the parapet of the landing, are the most northern or advanced body of columns, originally 12 in number, but of which, in Sir R. K. Porter's time, only one remained. At 71 feet southward from these, stood the central phalanx of 36, at intervals of 22 feet 2 inches from each other, of which only 5 now remain: the bases, however, of all the others are in their places, though most of them much mutilated. To the east and west of this group are two other groups of 12 each, whereof 5 still remain in the eastern one, and 4 in the western. The form of the columns which compose the three smaller colonnades at the front and sides of the main body is the same in all. The total height of each column is 60 feet, of which the shaft from capital to base occupies 44; the circumference of the shaft is 16 feet. The base consists of a plinth 8 inches high, and 24 feet 6 inches in circumference, from which rises the pedestal in the form of the cup and leaves of a pendant or inverted lotus; above this is a torus one foot deep, and upon this again, a cincture connecting the base with the shaft only 2 inches deep. The total height of the base from the cincture to the plinth measures 5 feet 10 inches. The capitals consist of two demi-bulls, comprising the fore-part of two bulls with head and fore-legs overhanging the shaft on either side, the bodies connected in the middle, and sustaining a sort of abacus; the heads of the animals project very considerably beyond the shaft, and form a kind of bracket to sustain the entablature. The columns of the central group are only 55 feet high, and differ considerably from the others; the shafts are fluted, and about 35 feet in length, and the capitals which resemble those of the great portal, occupy a large proportion of the height, and are adorned with a series of small scrolls, one above another, beneath which, and immediately above the necking, the shaft presents a bulging appearance, widening rapidly at the lower part, and gathering in gradually towards the scrolls, then spreading out again in the shape of a calyx or cup to receive the scrolls.

Eastward of this hall, and towards the mountainous side of the platform is situate a large mass of ruins, consisting of portals, passages, &c., the plot of ground on which they stand is about 95 paces from east to west, and 125 paces from north to south. In the centre are scattered fragments of columns and other stones, and in the interior there seems to have been a group of 76 columns.

To the south-west of the hall of Forty Columns, is a building elevated on a platform about 8 feet above the plane of the colonnades, which measures 170 feet from north to south, and 95 from east to west. It is approached from the west by a double flight of steps, which appear to have been enriched with sculpture similar to those of the great platform; another flight on the south extends the whole width of the terrace, the landing place of which is 48 feet long by 10 wide: the east side is buried in fallen ruins. The platform outside the building is occupied with fragments of portals, colossal statuary, &c. "From the western landing-place two portals lead into a room 48 feet square; it has two doors on the north, two to the west, one to the south, and, originally, two to the east. On three sides of the room are several square-headed niches, each excavated in one solid stone to a depth of 3 feet, 5 feet high, and 6 feet wide; they appear to have been exquisitely polished within, while upright lines of cuneiform characters run along their edges. Four windows 10 feet high, open to the south. There is another apartment of the same building 30 feet by 48, open to the south."

South-east of this building is another large edifice covering a space of 160 feet from north to south, and 190 feet from east to west; the plan seems to have been very regular, and consists of a polystylar hall of 36 columns, arranged in 6 rows of 6 each, surrounded with no less than 10 portals. The ground is covered with fragments, and beneath the pavement has been discovered a subterraneous aqueduct. To the west of this, and 100 feet south of the previous building, have been found traces of columns belonging to a smaller structure, and amongst them Le Bruyn discovered a staircase leading to a subterranean apartment.

The above are the principal edifices of Persepolis; there are some others of smaller size, which we do not think necessary to describe; the entire area too, which is equal to nearly thirty acres, is covered with innumerable fragments of various descriptions. Excavated out of the rock at the east side of the platform are two tombs, which are probably of the same date as the structures we have been describing; they are about 400 yards apart, and each contains a chamber about 30 feet wide, 18 deep, and 10 or 12 high; the façades are richly sculptured in both cases.

About four miles from this place are the sculptured tombs, called by the natives Naksh-i-Rustam, the entrances to which are nearly 60 feet above the general surface of the ground. One of the tombs consists of a chamber 35 feet long, 7 broad at each end, and 8 in the middle; in the sides are three arched recesses cut out of the rock, and measuring 9 feet in length, by 5½ in breadth. The roof of the chamber is arched, and its height measures 10 feet at the highest point. Opposite these tombs is a square building about 24 feet wide, and 35 high, constructed of white marble. At about 11 feet above the ground is a small doorway, which gives access to a chamber about 12 feet square, and 20 feet high, the roof being composed of two immense slabs of marble. On the outside the walls are varied with many oblong recesses, and are surmounted by a cornice enriched with dentils, that on the north side being formed of a single slab 22 feet 6 inches in length.

A building somewhat resembling a pyramid exists amongst the ruins of Pasargadæ, and is thus described by Mr. Morier: "It rests upon a square base of large blocks of marble, which rise in seven layers pyramidically. It is in the form of a parallelogram, the lowest range of the foundation is 43 feet by 37; and the edifice itself, which crowns the summit, diminishes to 21 feet by 16 feet 5 inches. It is covered with a shelving roof, built of the same massy stone as its base and sides, which are all fixed together by clamps of iron. Around it, besides a great profusion of broken marbles, are the shafts of 14 columns, once, perhaps, a colonnade, but now arranged in the square wall of mud which surrounds the whole remains." This monument contains a small and plain chamber; it is considered by some to be the tomb of Cyrus, but the Mohammedan writers call it the tomb of the mother of Solomon.

The fire-altars, which are of not unfrequent occurrence, consist often of a single upright stone about 12 feet high, and 3 or 4 feet square at the bottom, being slightly pyramidical, and therefore of somewhat smaller dimensions at the top, in which there is a deep hollow to receive the fire.

A rude, low wall of large stones forms an enclosure round the altar, having an entrance in one of its sides. Sir W. Ouseley observed several structures resembling those of the Druids in our own country; he mentions one at Darabgerd, which consisted of an irregular cluster of large, rude stones, some of which were from 20 to 25 feet in height. One, taller than the rest, stood in the centre, and another towards the west resembled a table or altar, being flat at the top; and under two or three others were recesses or small caverns.

It would be useless to attempt any description of the details of the style, with such slender information; some idea may be formed from the above descriptions, and for further information we must refer the reader to the writings of those travellers who have visited the spot, amongst whom we may mention Porter, Ouseley, Morier, Rich, Niebuhr, Le Brun, and Chardin.

PERSIANS, or PERSIC ORDER, in architecture a name common to all statues of men, serving instead of columns to support entablatures. They only differ from caryatides, in that the latter represent women.

The Persian is a kind of order of columns, first practised among the Athenians, on occasion of a victory their general, Pausanias, obtained over the Persians. As a trophy of this victory, the figures of men dressed in the Persian mode, with their hands bound before them, and other characters of slavery, were charged with the weight of Doric entablatures, and made to supply the place of Doric columns. Persian columns, M. le Clerc observes, are not always accompanied with the marks of slavery; but are frequently used as symbols of virtues, vices, joy, strength, valour, &c., as when made in the figures of Hercules, to represent strength; and of Mars, Mercury, Fauns, Satyrs, &c., on other occasions. *See* CARYATIC ORDER.

PERSPECTIVE (from the Latin *perspicio*, to see,) the art of representing objects on a definite surface, so as to affect the eye when seen from a certain position, in the same manner as the object itself would, when the eye is fixed on the point in view.

The art of perspective owes its birth to painting, and particularly to that branch of it which was employed in the decorations of the theatre, where landscapes were principally introduced, and which would have looked unnatural and horrid, if the size of the objects had not been pretty nearly proportioned to their distance from the eye. The ancients must, therefore, have had considerable knowledge of this art, though the only ancient author from whom we can obtain any information relative to its antiquity is Vitruvius, who, in the proem of his seventeenth book, informs us, that Agatharcus, at Athens, was the first who wrote on this subject, on occasion of a play exhibited by Æschylus, for which he prepared a tragic scene; and that afterwards the principles of the art were more distinctly taught in the writings of Democritus and Anaxagoras, disciples of Agatharcus, which are no longer extant. The perspective of Euclid and of Heliodorus Larisseus contains only some general elements of optics, that are by no means adapted to any particular practice; though they furnish some materials that might be of service even in the linear perspective of painters. Geminus of Rhodes, who was a celebrated mathematician in the time of Cicero, hath likewise written on the subject. It seems probable that the Roman artists were acquainted with the rules of perspective, from the account given of their scenic representations; but of the theory of this art among the ancients we know nothing—perspective, no doubt, having been lost when painting and sculpture no longer existed. John Tzetzes, who lived in the twelfth century, speaks of perspective as if well acquainted with its importance; and the Greek painters, who were employed by the Venetians and Florentines in the thirteenth century, seem to have brought some knowledge of it into Italy. The disciples of Giotto are commended for observing perspective more than their predecessors had done; they lived in the beginning of the fourteenth century.

The Arabians were not ignorant of this art, as we may presume from the optical writings of Alhazen, who lived about the year 1100, cited by Roger Bacon, when treating on this subject. Vitellus, a Polander, about the year 1270, wrote largely and learnedly on optics; and our own Friar Bacon, as well as John Peckham, Archbishop of Canterbury, treated the subject with surprising accuracy, considering the times in which they lived.

The most ancient authors who professedly laid down rules of perspective, were Bartolomeo Bramantino, of Milan, whose book, entitled *Regole di Perspettiva, e Misure delle Antichita di Lombardia*, is dated 1440; and Pietro del Borgo, who is supposed to have died in 1443. He supposed objects to be placed beyond a transparent tablet, and endeavoured to trace the images, which rays of light, emitted from them, would make upon it. His work is not now extant; but Albert Durer constructed a machine upon the same principles, by which he could trace the perspective appearance of objects. In 1450, Leon Battista Alberetti wrote his treatise *De Pittura*, in which he treats principally of perspective.

Balthazar Peruzzi, of Sienna, wrote his *Method of Perspective*, published by Serlio in 1540. To him, it is said, we owe the discovery of points of distance, to which all lines that make an angle of 45° with the ground line are drawn. Guido Ubaldi, another Italian, soon after discovered that all lines parallel to each other, if inclined to the ground-line, converge to some point in the horizontal line; and that through this point, also, a line drawn from the eye, parallel to them, will pass. His *Perspective* was printed at Pessaro in 1600, and contained the first principles of the method afterwards discovered by Dr. B. Taylor. In 1583, a book was published by Giacomo Barozzi, of Vignola, commonly called Vignola, entitled, *The Two Rules of Perspective; with a learned Comment, by Ignatius Dante.* In 1615, the work of Marolois was printed, in Latin, at the Hague, and engraved and published by Hondius. And in 1625, Sirigatti published a treatise of perspective, which is little more than an abstract of Vignola's. The art of perspective has been gradually improved by subsequent geometricians, particularly by Professor Gravesande and Dr. Brook Taylor. The latter did not confine his rules, as his predecessors had done, to the horizontal plane only, but made them general, so as to affect every species of planes and lines, whether parallel to the horizon or not; and thus the principles were made universal. Farther, from the simplicity of his rules, the whole tedious process of drawing out plans and elevations for any object is rendered entirely useless, and therefore avoided; for by this method, not only the fewest lines imaginable are required to produce any perspective representation, but every figure thus drawn will bear the nicest mathematical examination.

Vanishing points, in every position, were known to Guido Ubaldi; and Gravesande not only understood the use of vanishing points, but the use of directors also, in the representation of a point, prior to the appearance of any thing published by Brook Taylor; but the latter has extended his theory not only to vanishing points, but to the vanishing lines of planes in every situation, which, when once ascertained, the representation of an object is found by the same means in each plane, consequently with the same facility. Hamilton seems to be the first writer who introduced the

practice of setting the radial, or parallel of the original line from the vanishing point, upon the vanishing line, and the original line from the intersecting point upon the intersecting line, in order to ascertain the representation of any point, or any part or parts of the original line, and to find the originals from the representations given. This author is the first who has applied the harmonical division of lines to perspective. Noble's *Perspective* contains several inventions; particularly his methods of drawing indefinite representations to inaccessible vanishing points, both by scales and other means. Thomas Malton's treatise on this subject is also an able performance.

In the following list will be found the names of some of the principal writers on perspective, with the dates of their performances, down to a comparatively modern period. Some of these authors have been already mentioned; but in addition, several mathematicians of eminence have written on perspective; the latter have treated the art as the subject of pure geometry, as it really is. The performances of Dr. Brook Taylor, Gravesande, Wolf, De la Caille, and Emerson, especially, are truly valuable, from the perspicuous simplicity and universality with which they have treated the subject.

FOREIGN AUTHORS.

	Dates.		Dates.
Guido Ubaldas	1600	Andrea Pozzo — two treatises	1700 & 1707
Maroloi	1615	Bernard Lamy	1701
Marolois - Vredeman - Friese, the Jesuit	1619	Gravesande	1711

ENGLISH AUTHORS.

Humphrey Ditton	1712	Ware	1768
Moxon	1712	Priestley	1770
Brook Taylor — two treatises	1715 & 1719	Edward Noble	1771
Langley	1730	Thomas Malton	1775
Oakley	1738	Bradberry	1775
Hamilton	1738	Shiraton	1775
Sirigath (translated by Ware)	1754	Wood	1797
Kirby	1760	Douglas	1805
Highmore	1763	Edwards	1806
Fournier	1764	W. Daniel	1810
Cowley	1765	D. Cresswell	1811
Ferguson	1765	Milne	1812
		Hayter	1813

Within the last few years, writers on perspective have been so numerous, that it is impossible, as indeed it is unnecessary, to enumerate them.

We shall now proceed to describe the art of perspective, in such a manner as will, we trust, be found a very easy way of acquiring a general knowledge of the subject. Let the student place himself in a darkened chamber, and then let him make a small hole, not larger than a pea, in the door or window, opposite to some remarkable objects, such as houses or trees, the distance of which should be at least equal to their height, and may, with propriety, be two or three times that distance; and the experiment will be most agreeably conducted, when the sun shines strongly on the surfaces facing the hole. If a sheet of paper, or any white screen, be placed within the room before the hole, an image of the external objects opposite the aperture will be depicted upon it. The image will be beautiful, although the outline of the objects will not be very well defined, nor their colours very distinct, for reasons which the study of optics will fully explain. The instruction, however, to be derived from the experiment, will, for the present object, be the same. It will be observed that the images of all objects are inverted; and, to understand this, the student must be reminded of the rectilinear motion of light. The image on the screen can, of course, be formed only by those rays of light which enter the chamber at the aperture, and it will be admitted that the rays from the top of the external objects cannot proceed in a right line to the screen, unless they proceed to the bottom of the screen, and the objects on the left hand will be on the right of the image. That the rays of light from the objects cross each other at the aperture, and spread afterwards as they advance, may be proved by varying the distance of the screen; the size of the image upon which is enlarged by drawing it back, and lessened by placing it nearer the aperture. The student must further be informed, that if he could trace the image on the screen exactly as it is there delineated, he would, on reversing the screen, have an outline of the external objects in accurate perspective. As the proportions of the several parts, therefore, are not altered by the inverted position of the image, they may be contemplated and compared with the original objects, as if no inversion took place. Suppose the front of a single house to be parallel to the surface of the screen, and its centre very nearly opposite to the centre of the aperture, its image upon the screen will be of the same shape as the front itself is known to have, and its dimensions will be obtained by a rule easily discoverable; for the image will be very nearly as much less than the original as the distance between the original and the aperture. This estimate of the proportion between the image and the object, would not require the qualifying term *nearly*, but would be correct, if the aperture were exactly opposite the centre of the front of the house; but we have supposed the aperture to be nearer one side of the building than the other, in order that the rays from the nearest gable of the house may pass through the aperture. This being attended to, there will be an image of the gable end upon the screen; and the size and shape of this part of the image must be particularly noticed. It will be found, that, though the gable may be in reality as broad as the front, its image is extremely narrow; that its ground-line, instead of being level with that of the front, inclines more and more towards the top as it recedes from the eye, and that the further edge of the inclined roof inclines to this line with a greater degree of inclination than the original is known to have: thus, besides the narrowness in point of breadth, the height of the most distant corner of the gable is in the image shorter than the hithermost corner. This visual contraction of surfaces is called fore-shortening.

To understand how it happens, let the student suppose a thread stretched from any given point in the most distant angle or vertical edge of the gable to its image on the screen, or spot on which it would fall by taking a rectilinear course; let another line be supposed to be drawn from an opposite point of the nearest angle of the gable, and it will be perceived that as these lines, like the rays of light, cross the aperture, they will, at the screen, form but a very narrow opening; and as the breadth of the image cannot be greater than this opening, the breadth of the gable must be inconsiderable on the screen. It will be obvious at the same time, that the more nearly the gable is taken in front, the greater will be the breadth of its image, while that of the apparent extent of the front will be proportionally contracted. The inclination of the ground-line of the gable will be explained, by supposing lines to be drawn from the four corners or limits of the gable, to their respective places on the screen; for the line which bounds the further side of the gable must have a less image on the screen than the hithermost, because it is more distant, and at an intermediate distance, any vertical line in the gable must have an intermediate height; therefore, there

must be in the picture a gradual rising of the ground-line towards a point horizontally opposite the place of the aperture:—Now the whole art of perspective consists in observing rules which teach us to discover the diminutions of all objects seen obliquely, like the gable-end of the house. To render this experiment, and the inferences drawn from it, perfectly clear, it ought to be tried and fully considered. It will then speak to the eye, and the object to be obtained by perspective can scarcely be misunderstood, whereas the impression of mere words is speedily effaced.

To prevent any incorrect inference, we shall, however, refer to fig. 1, where, let C D represent the window-shutter of the darkened chamber, and *g* the aperture in it, A B an external object, and E F the screen which receives its image. It must be observed, that the darkened chamber is used only as a means of separating the rays which form an image from any other; and that if the direction of the rays could be ascertained as much before the shutter, as they are here behind it, an image of the original object would be obtained of the same size as that upon the screen, and in its erect position, because the rays have not crossed. Accordingly in the practice of perspective, the rays of light from an object are always supposed to be intercepted as they converge to the eye at some point, as at *h*, between the original object and the eye. In the experiment, therefore, the aperture in the window-shutter must be considered as representing the pupil of the eye, the darkened chamber of the eye, and the screen the retina, or as a means of rendering visible the pictures which the eye receives of visible objects. We need not observe, that a larger aperture, with a convex glass set in it, would, in fact, form a camera obscura, and a very distinct image would be painted on the screen, at the focus of the glass, but the experiment would then be less simple, and the direction of the rays not so evident. Without a glass, the distinctness of the picture is sufficient to be agreeable, when the eye has been sometime in the chamber.

To consider the foundation of perspective in another point of view, let A B C D, fig. 2, represent a house, seen by the eye at N. The eye N, is supposed to be opposite the corner *q* of the house; its distance from which is equal to N *q*, and its height five feet from the ground. The situation of the eye corresponds to that of the hole in the window-shutter of the former experiment, and the picture of the house formed in the eye itself corresponds to that which the screen received. In this situation, as in every other, straight lines drawn from every part of the house to the eye, represent the direction of the rays which form the images of those parts respectively, and thereby render the house visible. The eye, it must be understood, is fixed upon the point *q*, directly before it, and in order that no sensible deviation may be possible, we may suppose it to be looking through a very small aperture in a piece of thin brass, *g*. If now a transparent plane, for example a pane of glass, K L, be interposed between the house and the eye, at a short distance from the eye, the whole of the house will be seen through the transparent plane, although the latter is, comparatively with the house, of very small dimensions, because the rays, in proceeding to their point of convergence at the eye, have approached each other in a proportion inversely as the distance; that is, at half the distance from the object, they only extend over half the space contained between the points of emission; at one-fourth of the distance from the eye, they only take up one-fourth of the space; and the same proportion for other distances. Suppose the pane of glass to be within arm's reach of the eye at N, and that it is coated with gum-water or isinglass, so as to receive the marks of a pencil, without having its transparency destroyed; trace the outlines of the house upon the glass, by observing and following exactly the direction in which they are seen through the small aperture in the piece of brass. When this is done, it will be found that the real or measured extents, forming the different external surfaces of the house, are represented by extents modified by the distance and obliquity of these surfaces to the eye; in short, as shown in the figure, a representation of the house in true perspective will be obtained, in the given situation of the eye. To young persons, the difficulty of understanding an explanation of this kind is occasioned by their indistinct perception of the relation between the rays and lines from a real object, and the projection of those lines upon a flat surface, as a sheet of paper. It appears confusing to them to say that the eye is opposite to the corner *q* of the house, and yet to represent it at N on one side. Unless this difficulty be overcome, and the mind can form a distinct image of the direction which the line shown on paper would have if drawn from a real object, perspective diagrams will be contemplated with pain, and the remembrance of them will soon be effaced. We shall therefore propose a little experiment, which we recommend to be tried by those who feel the difficulty alluded to.

Let a small model of a house be made of wood, and to every corner of it which can be seen in any one situation, affix a thread of silk, two or three times as long as the model of the house is high. These threads will represent the rays of light proceeding from the corners A B C D, *f k l m* of the house in *Figure* 2. Let the threads be drawn through a hole in a piece of thin brass, just large enough to admit them to be moved freely. The hole in the piece of brass will represent the eye. Let small weights be attached to the extremities of the threads which have been passed through the hole in the brass; the threads being thus stretched, will form a right line from the house to the brass, and the apparatus will be ready for elucidating the nature of perspective. While the model of the house remains stationary, let the position of the brass be varied, sometimes placing it higher, sometimes lower, at different distances, and towards different sides; and let the angles formed by the threads in each situation be attentively considered, by the observer placing himself behind the brass, and supposing himself to regard the house as if he saw it through the hole. Let him after each remove of the brass, suppose that the threads representing the rays of light, without altering their direction, were to pass through a sheet of paper, interposed at any distance between the brass and the house, and he would find that by drawing lines to join the points thus obtained, an outline representation of the house would be produced, and this representation would be in true perspective. For any one situation, it would not be a troublesome matter to perforate a piece of paper, to be slipped upon the threads without distorting them; and for other situations, a good idea of what the representation would be, or, in other words, of the perspective space between any given points, would be obtained by measuring the openings between the threads at equal distances from the brass. After the trial and proper consideration of this experiment, it will be easy to form a tolerably correct idea of the perspective appearance of any object, or assemblage of objects, and not difficult to exhibit that appearance on paper. In perspective diagrams, lines must be drawn to represent the rays, the direction of which in this experiment is indicated by threads, and as the view of an object varies from the point in which it is seen, the situation of the eye, both in height and distance, must be laid down upon paper, on which the perspective drawing of an object is to be made, unless we propose to look at the object itself as through a transparent plane. The question then occurs, how shall the position of the eye be

designated on paper? It can no way be represented so clearly as by placing it on one side, as shown in the figure, or by placing it vertically beneath the object to be drawn, as represented in *Figure* 12.

By whatever means the representation *t u*, *Figure* 2, of an object A B C D, is obtained, if the outline be accurate, and viewed at a proper distance, it is plain it will make an outline of the same form in the eye as the object itself; and if the colouring were equally perfect, the eye might mistake the figure for the original. But even when colours are not employed, correct dimensions give the whole a pleasing appearance, and constitute the first great requisite to every good picture.

Having thus endeavoured to explain the nature of perspective, we may next advert to the limits of vision. We may consider the eye, in whatever direction we look, as situated in the centre of a sphere, which we may suppose to be represented by the circle E K F I, *Figure* 3. The hemisphere E L F is behind the eye, and therefore obviously invisible; and it is also certain, that the eye, looking forward horizontally to K, cannot take in at once the whole of the hemisphere E K F. So far from this, it cannot take in a larger angle than S R T, which is but half a hemisphere, or equal to 90 degrees. And as the rays which the eye takes in, extend all round to an equal distance from the central ray K R, it follows that the whole of the rays which enter the eye at once, will be in the form of a cone, of which the apex is at the eye; and of such a cone of rays, S R T may be considered as the profile. It is however found, that to have an agreeable view of large objects, such as buildings, the angle of vision should not exceed 60 degrees, or one-third of an hemisphere; in other words, that we cannot distinctly see the whole of an object, unless its distance from the eye be at least equal to its height; and the appearance of a picture will be more agreeable, if not made to comprehend above 45, or at most 50 degrees; indeed, for small objects, or such as do not exceed the length of a foot in any of their dimensions, it is not advisable to exceed an angle of 30 degrees. As a picture therefore should never comprise more than the eye can easily take in at one view, a distance of 25 degrees on either side of the point of sight, may be considered a standard limit. Fifty degrees to the eye at B, are comprehended in the angle *x* R *y*; and we need scarcely observe, that the measure of an angle, is the space it takes up on the circumference of a circle, which has the point of the angle for its centre; a circle being always supposed to contain 360 degrees. Hence, if the lines forming the angle *x* R *y* were extended, the angle *v* R *t* would still be only one of fifty degrees, because, whatever were the size of a circle drawn from the point R, through its two legs, if that circle were divided into 360 parts, the number of those parts enclosed by the angle, could not be more than fifty.

We shall now proceed to the definition of the terms used in treating of perspective, and then show the method of putting into perspective, those forms which may be considered as the elements of all others.

Definitions.—1. An *original object* is any object whatever, which is rendered the subject of a picture.

2. *Original planes* or *lines* are the surfaces or lines of original objects.

3. *Perspective plane* is the surface on which a picture is delineated. It may be here observed, that painters regard the frame of a picture merely as an aperture through which original objects are seen; and they therefore consider the perspective plane to be transparent, to admit of this view. It is on this account that the perspective plane is frequently called the *transparent* plane.

4. *Ground-plane* is the earth or surface on which stand the objects to be delineated, as well as the spectator.

5. *Ground-line* is the line on which the perspective plane is supposed to rest.

6. *Visual rays* are those which, passing through the transparent plane, render original objects visible.

7. *Principal visual ray* is that which passes through the axis or centre of the eye, and the course of which, therefore, from the perspective plane, is shorter than any other, because it is perfectly direct. Its height above the ground-line is, of course, always the same as that of the eye.

8. *Point of sight* is that fixed point from which the spectator looks upon the perspective plane, when any original object is delineated.

9. *Centre of the picture* is that point of the perspective plane which is exactly opposite the point of sight, that is, where the principal visual ray enters the transparent or perspective plane. It must, therefore, be carefully distinguished from the measured centre of any picture, as it can never exceed the height of the eye from [illegible].

10. *The distance of the picture, or point of distance*, is the distance between the eye and point of sight, and the centre of the picture.

11. *Vanishing points* are those points to which all lines inclined to the picture appear to converge, and which those lines meet when produced. Vanishing points have no place in a finished picture; they are used to facilitate drawing in perspective.

12. *The horizontal line* is a line parallel with the horizon, at the height of the eye,—that is, it passes horizontally through the centre of the picture.

Distance of a vanishing point is the distance upon the vanishing point on the picture to the eye of the spectator. It may also be proper to remind some, of the difference between a perpendicular and a vertical line or plane: a vertical line points directly to the centre of the earth; it is therefore at right angles to the plane of the horizon, and is the same with the direction of a plumb-line: a perpendicular line is any line which is at right angles to another; it may therefore be sometimes a vertical line, sometimes a horizontal one, or in any other position, according to the direction of the line or surface with which it forms a right angle.

Methods of putting squares into perspective.—Suppose a square to be traced upon the ground at some distance before us; that we find, upon admeasurement, the length of each side to be 8 feet, and that we are opposite the centre of the nearest side, at the distance of 18 feet. We know, that if we wish to obtain what is called a ground-plan of this square, we must represent it by a square upon paper, as in *Figure* 4, and thus we shall have its real appearance, supposing the eye to be looking down upon it, just over its centre; but looking upon it obliquely, as we have stated, and with the eye at the height of 6 feet from the ground, we are convinced, from the nature of perspective, as before explained, that the side nearest to us will make a longer line upon the retina than any of the rest. The question is, therefore, to obtain the true appearance of the whole square,—that is, the true form of the image it makes on the retina. In the first place, determine the scale to be observed,—that is, what space shall correspond to a foot of the original. For example, suppose one-tenth of an inch; then draw a line, A B, *Figure* 5, eight-tenths of an inch long, and another line, H D, parallel with this base-line, at the height of six-tenths of an inch from it. Raise a perpendicular from the centre of the line A B, and the point C, in which cuts the horizontal line, will be the centre of the picture. From C on the horizontal line, set off the distance at which the square is seen, which will here be

eighteen-tenths of an inch, and the point of distance D will be obtained. From A, draw the line A C; and from B, the line B C; then from A, draw the line A D, and to the point *h*, in which A D intersects B C, draw a line *g h*, parallel with the ground-line A B; then will A *g* B *h* form the perspective outline of the square required. Let it be supposed that the square above described is viewed by an eye situated opposite one of its corners, as in *Figure* 6. Draw a base-line, B L, as before, and on each side of any assumed point, *k*, set off half the measured length of the diagonal of the square, viz., half the distance between the corners *y* Z, *Figure* 4. Parallel to the base-line, at the height of six-tenths of an inch from it, draw the horizontal line P H D, and raise from *k* the perpendicular *k* C. From F, draw the line F C, and from G, the line G C. On each side of the centre C, set off on the horizontal line the points of distance P D, and from each side of them draw lines to the centre of the base *k*; then from *a*, draw the line *a* P, and from *b*, the line Z D, and the diagonal view, *a b f k*, of the square, will be completed.

We shall give one more example respecting squares:—Suppose we have a square pavement, composed of equal alternate pieces of black and white marble; the total number of small pieces to be 144, and each of them 1 foot square, as—

Here there will be six black and six white pieces on each side of the square. Suppose the spectator to stand opposite the middle of the third square on the left, and that, for greater clearness, the scale be two-tenths of an inch to a foot, with the eye 5 feet above the ground, but at the distance of 18 feet, as before. Draw a base line *r k*, and divide a part of it into as many equal divisions as there are squares on one side of the original, as 1, 2, 3, 4, &c. These divisions, by the scale now adopted, will each be two-tenths of an inch. Draw the horizontal line at the distance of 5 feet (according to the scale) from the base. From the middle of the space between 2 and 3, raise a perpendicular, and to the point C, in which it cuts the horizontal line, draw lines from the commencement and the termination of the divisions on the ground-line, viz., *r* C and 12 C. From C, set off the distance C D, 18 feet, for the distance of the eye. Draw the line *r* D; and from *e*, where it intersects the line 12 C, draw a line, *e f*, parallel with the base-line *r k*; then will *r f e* 12, give the boundaries of the pavement. To obtain the reticulations, draw lines from each of the divisions, 1, 2, 3, &c., on the base-line, to the centre of the picture C, and from each of the same divisions to the point of the distance D. The lines drawn from the divisions to C, from the right and left sides of the small squares, and the lines drawn from the divisions to D, give the points on the line C 12, from which the horizontal lines may be drawn to form the other sides of the squares. Or, after all the lines are drawn from the divisions on the ground-line to the centre C, and also the line *r* D, the remaining sides of the squares may be obtained by drawing parallel lines through the various points in which the part *r e*, of the line *r* D, intersects the lines drawn to the centre C.

It is often thought by those who are commencing this study, that representations such as the one now given, have no resemblance to the originals; but if they be examined, as every picture ought to be examined, opposite to the point of sight, and at the distance for which they are drawn, the idea of their incorrectness will disappear; to render the illusion the more complete, the figure should be viewed through a small tube or aperture, to prevent the intrusion of surrounding objects. It must also be observed, that diagrams upon paper have frequently, for the sake of convenience, a vanishing point so near, that the eye has not the power of distinct vision at the distance for which they are drawn. Such designs, therefore, although correct in principle, will not appear correct to the eye unless enlarged.

To put a circle into perspective.—The perspective or oblique view of a circle, is an ellipse, and it is usually obtained by drawing a square of a size just sufficient to contain the circle, and dividing it into small circles, then putting the divided square into the perspective, and drawing within it a line through the corresponding parts of the small squares, and this line will be an ellipse. Thus, to obtain the perspective of a circle E F G H, fig. 8, draw round it the square A B C D. Divide the square into small squares, the number of which should be increased in proportion to the exactness with which the perspective curve must be obtained; draw also the diagonals, C B and A D. Throw the square and reticulations into perspective, as represented in fig. 9, where C is the centre of the picture, and D the point of distance; then draw the curve by hand through the parts corresponding to those through which the circle passes in fig. 8. The perspective view of a circle will be an ellipse, whether the square opposite the middle of one of its sides, as in fig. 9; or even with one of its angles, as in fig. 10, where B C is the line of sight; or at a distance on one side, as in fig. 11, where L C is the line of sight. The point of distance, in figs. 10 and 11, is the same as in fig. 9, though in fig. 11 it could not be drawn without extending beyond the limits of the plate.

To put a triangular prism into perspective.—To represent in perspective a triangular prism or solid, standing vertically upon one of its ends, and viewed by an eye just opposite one of its angles; draw by admeasurement a plan of a prism, as *a b c*, fig. 12; then draw the line G K across the outermost boundary of the triangle, and make E F parallel with G K. From *e* let fall the line *e d*, perpendicular to G K. On *c d* set off the measured distance of the eye from the prism, and mark the place of the eye at *d*. From *a* and *b*, draw lines meeting each other in *d*. From *d*, draw the line *d m* parallel with *a c* of the triangle, and on the other side of the line *d l* parallel with *b c*. From *e* raise the perpendicular *e f* to the measured height of the nearest angle of the prism to which the eye is opposite. On *e f*, measure the height of the eye from the ground-line G K, and draw the horizontal line H H. Take the distance *c m*, set it off on each side from *n*, and it will give the vanishing points V P and V. Draw the lines *e* V P and *e* V. Then from *o* and *p*, where the lines from *a* and *b*, in proceeding to the eye, cut the line E F, draw the lines *p q* and *o s*, parallel with *e f*. Draw the lines V *x f*, and *f w* V P, and the perspective outlines *w f x r e z*, of the prism, whose base is equal to the triangle *a b c*, will be obtained, and may be finished by shading it according to the direction in which the light falls upon it. This mode of drawing from a ground-plan is extremely useful, and well calculated to show the difference between the visual and real dimensions of objects. The outlines of the house A B C D, in fig. 2, were obtained by it; it should be rendered familiar by frequent practice on figures in different positions.

To put a cube and cylinder into perspective.—As the base of a cube is a square, it may, when viewed as in the present example, opposite one of the angles, be put into perspective by the same process as the square in fig. 13, and figs. 9, 10, and 11, will explain the manner in which the perspective of a square, seen in other positions, may be obtained. Having then obtained the base, we shall find that when H is the horizontal line, P D the points of distance, and *a b* half the measured length of the diagonal of the cube, the perspective of the base will be represented by *a f d g*. Make the height of *a c* equal to the measured length according to the scale, of one of the sides of the cube, then draw the lines *c* D and *e* P.

From *f* and *g* draw lines parallel with *a e*, for the sides of the figure; draw the line *e* F to a perpendicular let fall from the horizontal line at P to M. From F draw a line to any part of the horizontal line, as to L, and draw from M a line to meet this in L. To *f* draw the line *f h*, and to *d* the line *i d*; then from *h* and *i* raise perpendiculars to intersect F L, and from the points of intersection draw the lines *p l* and *r k*; thus will be obtained the perspective outline of the cube *k l f a g o e*. If the cube had not been viewed directly opposite one of its angles, the points of distance would not on each side have coincided with the vanishing points, and the vanishing points would have been best obtained as for the triangular prism, fig. 12.

The procedure of a parallelopiped, is essentially the same as for a cube. To put a cylinder into perspective, first proceed as for a cube or parallelopiped, draw on the perspective of each, and such an ellipse as it will admit; let the longer or conjugate axes be equal, and join the opposite extremities of these axes by two parallel lines, as shown in *Figure* 14. Having thus obtained the perspective of the cylinder, it only remains to erase the lines which belong to the cube or parallelopiped.

Of shadows, and description for drawing perspective.— Having now shown the mode of putting into perspective those elementary forms which enter into the composition of drawings of every description, we shall be obliged to be concise with the remainder of the subject. The student must be aware how much difference of position affects the visual appearance of objects. And that by a proper attention to this circumstance, the few rules which have been given, may be applied to subjects of considerable complication. To acquire a knowledge of the principles of perspective, it is recommended not merely to compare the plates with the printed page, but to copy the diagrams, and, for the sake of greater perspicuity, to do this on as large a scale as may be convenient. Afterwards, some treatise especially devoted to the subject may be perused, and perhaps Brook Taylor's and Matton's may be the best; for although these authors will require considerable attention, they have the merit of being sure guides.

With respect to shadows, the proper distribution of which give such life to perspective drawings, it may be useful to remark, that the shadow cast by any object, covers the precise space which that object would prevent the eye from seeing, if the eye were in the place of the luminous body. The position, therefore, of the luminous body must always be ascertained, and the shadow to be assigned to any object in a picture, will be a perspective view of the space which the eye would be prevented from seeing, if in the place of the luminous body. A few experiments with a candle at night will be an easy mode of gaining a little acquaintance with this subject; it must, however, be observed, that the shadow from a candle is every way larger than that part of the object which intercepts the rays; but in point of breadth, this never happens with the shadows of the sun. The reason is, that the rays from the candle considerably diverge, while those from the sun, on account of the immense distance of that luminary, have no perceptible deviation from parallelism. It must be remembered also, that strong reflections from surrounding objects will diminish the intensity of shades, and that not only the quantity of light which falls on an object, but the quantity which can be reflected to the eye, must be considered.

As it frequently happens that persons have occasion to draw in perspective, who have acquired no theoretical knowledge of the art; for the use of such, a great variety of machines have been contrived. Most of these machines are on optical principles; the camera obscura, which we have already described, is one of them, and the camera lucida is another. In praise of the latter, much has lately been said; but although it must be admitted to be a very portable and beautiful instrument, the acquisition of the proper art of using it is extremely difficult to all, and to some impossible. Its chief use will be, that of affording the means of contemplating the real perspective appearance of objects, and perhaps to obtain the position of a few points; but for very minute delineation, it is of little value. For general use we may venture to recommend an instrument described by Ferguson, to whom the knowledge of it was communicated by Dr. Bevis. It has the advantage of other machines in two points; it may be constructed at a small expense by any tolerably skilful artisan in wood, and the use of it will constantly tend to render the practice of perspective drawing more easy, by the manner in which it produces the measure of surfaces or angles. It will therefore, better than most other instruments for the same purpose, supply the want of a more extended essay.

The machine in question is represented at *Figures* 15 and 16. *Figure* 15 is a plan, and *Figure* 16 a view of it on a larger scale. The same letters refer to the corresponding parts in both figures. A B E F is an oblong board, and X Y are two hinges on which the part C L D is moveable. This part consists of two arches or portions of arches, C M L, and D N L, joined together at the top L, and at the bottom to the cross bar D C, to which one part of each hinge is fixed, and the other part to a flat board, half the length of the board A B E F, and glued to its uppermost side. The centre of the arch C M L is at D, and the centre of the arch D N L is at C.

On the outer side of the arch D N L is a sliding piece, N, (much like the nut of the quadrant of altitude belonging to a common globe) which may be moved to any part of the arch between D and L; and there is such another slider O, on the arch C M L, which may be set to any part between C and L. A thread C P N is stretched tight from the centre C to the slider N, and such another thread is stretched from the centre D to the slider O; the ends of the threads being fastened to these centres and sliders. It is plain, therefore, that by moving the sliders on their respective arches, the intersection P of the threads may be brought to any point of the open space within those arches.

In the groove K is a straight sliding bar I, which may be drawn farther out, or pushed further in, at pleasure. To the outer end of this bar I, *Figure* 16, is fixed the upright piece H Z, in which is a groove for receiving the sliding piece Q. In this slider is a small hole R, for the eye to look through in using the machine; and there is a long slit in H Z, to let the hole R be seen through when the eye is placed behind it, at any height of the hole above the level of the bar I.

Suppose a house, *q s r p*, to be at a considerable distance beyond the limits of the plate, to obtain a perspective representation of it, place the machine on a table, with the end E F, of the horizontal board A B E F towards the house, so that, when the arch D L C is set upright, the middle part of the open space (about P) within it, may be even with the house when the eye is placed at Z, and looking at the house through the small hole R; and then fix the corners of a square piece of paper with four wafers, on the surface of that half of the horizontal board which is nearest the house.

To complete the arrangement of the apparatus for drawing, set the arch upright, as in the figure, which it will be when it comes to the perpendicular side T, of the upright piece S T, fixed to the horizontal board behind D. Then placing the eye at Z, look through the hole at R at any point of the

house, as *q*; and move the sliders N and O, till the intersection of the threads at P, is directly between the eye and the point *q*; then put down the arch flat upon the paper on the board, as *s t*, and the intersection of the threads will be at W. Mark the point W on the paper with the dot of a blacklead pencil, and set the arch upright again as before; then look through the hole R, and move the sliders N and O, till the intersection of the threads comes between the eye and any other point of the house, as *w*; this being done put down the arch again to the paper, and make a pencil-mark thereon at the intersection of the thread as before; obtain the point *p* in the same manner, and draw a line from that mark to the one at *w*. The line *p w*, thus obtained, will be a representation in true perspective of the corner *p q* of the house.

By thus bringing the intersection of the threads successively between the eye and other points of the outlines of the house, as *r s*, &c., and putting down the arch to mark the corresponding points, on the paper, at the intersection of the threads, then connecting these points by straight lines, the entire perspective outline of the house will be obtained. In like manner, find points for the corners of the doors, windows, &c., and draw the finishing lines from point to point. The perspective drawing thus produced, may then be completed, by shading it according to the manner in which the light is observed to fall on the original.

Great care must be taken, during the whole of the time, that the position of the machine be not shifted on the table; and to prevent such an accident, the table or support employed should be perfectly steady, and the machine fixed down upon it by screws or clamps.

It is obvious that a landscape, or any number of objects within the field of view through the arch, may be delineated, by finding a sufficient number of points, and connecting them by straight or curved lines, as they appear in the original objects.

The arch ought to be not less than a foot wide at the bottom, that the eye at Z may have a large field of view through it; and the eye should be then at least ten inches and a half from the intersection of the threads at P, when the arch is set upright. If the eye be nearer, the boundaries of the view at the sides near the foot of the arch will subtend an angle at Z of more than sixty degrees, which will not only strain the eye, but will cause the outermost parts of the drawing to have a disagreeable appearance. To avoid this it will be proper to draw back the sliding bar I till Z be fourteen inches and a half distant from P; then the whole field of view through the foot-wide arch, will not subtend an angle to the eye at Z of more than forty-five degrees: which will give a more easy and pleasant view not only of the objects themselves, but of their representations upon the paper on which they are delineated. Hence, whatever may be the width of the arch, the distance of the eye from it should be in this proportion: as twelve is to the width of the arch, so is fourteen and a half to the distance of the eye (at Z) from it.

If a pane of glass, previously coated with thin gum-water, and dried, be fixed in the arch, a person who looks through the hole at R, may delineate upon the glass the objects which he sees at a distance, and the delineation may be afterwards transferred to paper. By this means will be saved the trouble of putting down the arch to take the position of every point, but it will not be so easy to obtain a correct representation.

PERSPECTIVE OF SHADOWS.—The shadow of an object is no more than the projection of its contour upon one or more planes, from a given luminous point, and is therefore the dark space upon these planes, occasioned by the intervention of the object, which hides the rays of light from proceeding in straight lines. To avoid difficulties, the luminary, whether the sun or artificial light, is considered as a point, and the sun's rays are considered as parallel.

PROBLEM.—*Given the vanishing line of a plane, the image of a line insisting upon that plane, and its vanishing point; also the vanishing point of the sun's rays; to find the shadow of the line.*

Plate I. *Figure* 1.—Let A B be the vanishing line of the plane, *a b* the image of the line, V its vanishing point, and S the vanishing point of the sun's rays; join V S, and produce it to meet A B in *s*: join *b s* and *a* S, cutting each other in *c*, then *b c* is the shadow of the line required.

For the vanishing point of the line, and that of the sun's rays, are in the vanishing line of the plane of shade; therefore V S *s* is the vanishing line of the plane of shade; but the shadow is occasioned by the intersection of the plane of shade with the original plane, whose vanishing line is given; therefore the point *s*, the intersection of the vanishing line of the plane on which the line insists, with the vanishing line of the plane of shade occasioned by the line, is the vanishing point of the shadow.

Example to find the shadow of a cube.

Figures 2 and 3.—A B being the vanishing line of the plane of its base, and of the surface on which it rests; the edges *g d*, *b a*, *m n*, being supposed to be perpendicular to the base; then, if the picture be perpendicular to the original plane, the vanishing line of a plane of shade occasioned by the vertical arrises, will be perpendicular to the vanishing line A B; therefore let S *s* be the vanishing line of the plane of shade occasioned by the vertical edges, S being the vanishing point of the sun's rays, and *s* the intersection of the vanishing line of the plane of shade with that of the plane on which the shadow is to be thrown.

Join *b s* and *a* S, cutting each other in *c*; then *b c* is the shadow occasioned by the edge *b a*; join *c* B and *d* S, cutting each other in *e*, or, if necessary, produce them to cut in *e*, and *c e* is the shadow occasioned by the edge, *a d*, parallel to the plane of its base; also join *e* A and S *f*, cutting each other in *i*, or, if necessary, produce them to cut each other in *i*; then *e i* will be the shadow of the edge *d f*; lastly draw *i s*, which will complete the shadow of the cube, as required.

Figure 2 shows the shadow when the sun is before the picture: *Figure* 3 shows the shadow when the sun is behind the picture; and *Figure* 4, the shadow when the sun is in the plane of the picture.

Many more examples of the shadows of objects might be given, but if the principles here shown are understood, the student will not be at a loss to find the shadow of any right-lined object whatever. To find the shadow of any right-lined object, is no more than to find the shadow of the lines, or arrises, formed by the meeting of the sides, and those only of the lines forming the contour; if a circle be given, the circumference may be divided by parallel lines into parts, and the shadows of the points of division may be found by finding the shadows of the intercepted parts, then drawing a curve round the extremities. If it were required to find the shadows upon several planes; first, find the shadow in the plane on which the object rests; then, observe where the shadow meets the next plane; then, having the vanishing line of this second plane, observe where the vanishing line of the plane of shade cuts the vanishing line of the second plane; then the point of intersection is the vanishing point of the shadow in this second plane. See more of shadows under the article PROJECTION, where the principles apply as well to perspective as to orthographical projection.

PERUZZI, BALDASSARE, in biography, was born at Accajano, in the territory of Sienna, in 1481, in poor and dis-

tressed circumstances; his father having been reduced from a state of comparative affluence, by the civil wars which ravaged Florence and its territory. Baldassare exhibited his genius at a very early age; first by imitation of the works of others, and afterwards by original productions in the city of Volterra, where his family resided. Thence he went to Rome, where he placed himself with the father of Maturino; and becoming conspicuous for ability, he was at length employed by pope Alexander VI., and also in many churches and convents in that city, in which he produced pictures justly entitled to exalted praise.

Together with painting, he studied architecture; and practised it with considerable success. He was also renowned for his knowledge of perspective; and the works he produced in imitation of architectural projections, excited even the surprise and admiration of Titian. But his highest renown is founded upon works of a much more elevated class; viz., his paintings in fresco and in oil; in which he exhibited a taste and style not unworthy of Raphael. There is at Wilton a picture of his of the Four Evangelists in Glory, with their peculiar characteristic accompaniments, which bears ample testimony to the truth of this remark; and perhaps it is the only real specimen of his pencil in England. He wrote a treatise upon the antiquities of Rome, and a commentary on Vitruvius, but did not live to publish them; being poisoned by some who were probably envious of his reputation and talents, in 1536, at the age of 55.

PEST-HOUSE, a lazaretto, or infirmary, where goods, persons, &c., infected, or suspected to be infected, with some contagious disease, are disposed, and provided for.

PETER OF COLECHURCH, an architect and priest, who built the late London Bridge, in the reigns of Henry II. and his sons Richard and John.

PEW, or Pue, a wooden seat or bench used in churches, of sufficient length to contain several persons. The term has, of late years, been particularly applied to the closed boxes provided with doors, but is equally applicable to the open seats of a previous age, which are now again happily superseding the closed pews. We have many beautiful examples of such benches, some very richly carved; they consist, for the most part, of a low seat and back, fixed into a standard at each end, which is either plain or carved, and is sometimes finished at the top with a finial, boss, or poppy-head.

PHALANGÆ, a term applied by Vitruvius to wooden rollers employed to transport heavy weights from place to place.

PHAROS, or Phare, a lighthouse, or pile raised near a port, where a fire is kept burning in the night, to guide and direct vessels near at hand. The pharos of Alexandria, built in a small island at the mouth of the Nile, was anciently very famous, insomuch as to communicate its name to all the rest. It was so magnificent a structure, being built by the celebrated architect Sostrates, a native of Cnidos, or, as some say, by Deiphanes, the father of Sostrates, that it cost Ptolemy Philadelphus eight hundred talents. It had several stories, raised one over another, adorned with columns, balustrades, and galleries, of the finest marble and workmanship; to which some add, that the architect had contrived to fasten looking-glasses so artificially against the highest galleries, that in them could be seen all the ships that sailed in the sea for a great way; instead of which noble structure, there is now only a kind of irregular castle, without ditches, or outworks of any strength, the whole being accommodated to the inequality of the ground on which it stands, and which, it seems, is no higher than that which it should command. Out of the midst of this clumsy building rises a tower, which serves for a lighthouse, but possessing nothing of the beauty and grandeur of the old one. The colossus of Rhodes also served as a pharos. *See* Eddystone, and Lighthouse.

PHEASANTRY, a building or place constructed for the purpose of breeding, rearing, and keeping pheasants, which should always be near to, and well covered with, plenty of wood, in different states of growth; the whole being enclosed with a high fence, that the young may, as soon as possible, run freely through it, and pick up their food, &c.

PHENGITES, in the natural history of the ancients, the name of a very beautiful species of alabaster. It is a very rude and irregular mass, very friable, yet of a brightness superior to that of most of the other marbles, and excelling them all in transparency; it is in colour of an agreeable pale-yellowish white, or honey colour; the yellowish is more intense in some places than in others, and sometimes has an obscure resemblance of veins. It is very weak and brittle in the mass; and when reduced to small pieces, easily crumbles between the fingers into loose, but considerably large angular pieces, some perfect, others complex, irregular, or mutilated, and all approaching to a flat shape.

The ancients were very fond of this species in their public buildings; and the Temple of Fortune, built wholly of it, has long been celebrated. Its great beauty is its transparency, from which alone this temple was perfectly light when the doors were shut, though it was built without a window, and had no other light but what was transmitted through the stone walls. It was anciently found in Cappadocia, and is still plentiful there: it is also met with in Germany and France, and in our own kingdom in Derbyshire, and some other counties. It takes an excellent polish, and is very fit for ornamental works, where no great strength is required.

PHIALS, vases used by the ancients in the construction of vaults; they were made of a slightly conical form, so as to fit into each other, and were manufactured of a light material, so as to ease the weight and thrust of the vault.

PHIDIAS, in biography, an Athenian, the most celebrated sculptor of antiquity. His distinguishing character was grandeur and sublimity; and he particularly studied optical effect. To this purpose it is related, that having, in competition with Alcamenes, made a statue of Minerva to be placed on a column; the work of the latter appeared so finished when viewed on the ground, that it was universally admired, whilst that of Phidias seemed to be a mere rough sketch; but when both were seen from their destined situations, the beauties of the first were lost, while the second produced the most striking effect. After the battle of Marathon, he converted a block of marble, which the Persians had brought for a trophy of their expected victory, into a fine statue of Nemesis, the goddess of Vengeance. His reputation was so high at Athens, that Pericles regarded him as his particular friend, and appointed him superintendent of all the public edifices with which that city was decorated. One of his greatest performances was a colossal statue of Minerva, in the temple called Parthenon. In this work he displayed his skill in minute sculpture, no less than his grandeur of conception in the main figure. On the convexity of the goddess's shield was represented the battle of the Amazons, and on its concave surface the combat of the gods with the giants; whilst her slippers were adorned with the fight of the Centaurs and Lapithæ. On her breastplate was a Medusa's head. The base contained the birth of Pandora, with twenty figures of the gods. He is said to have been the first who brought the bas-relief to perfection. His fame and fortune excited envy, and several accusations

were brought against him, which he was enabled to repel. At length, he was charged with having introduced the portraits of himself and Pericles in the battle of the Amazons; and this being regarded as a kind of profanation, he was thrown into prison, where, according to Plutarch, he died. Others, however, affirm, that he escaped to Elis, where he afterwards executed his Olympian Jupiter, the most remarkable piece of sculpture in all antiquity. It was a colossal statue, sixty feet high, of incomparable majesty and dignity in its attitude and expression. The name of the artist was engraved on the base. The Eleans, in gratitude for this extraordinary work, settled upon his descendants a perpetual office, the sole duty of which was to preserve the lustre of the statue.

PIACHE, or PIAZZA, a covered arched walk, or portico. *See* PIAZZA and PORTICO.

PIAZZA (from the Italian *piache*) a portico, or covered walk, supported by arches. The word literally signifies a broad open place, or square; whence it also became applied to the walks, or the porticos around them. *See* PORTICO.

PICTS' WALL, in antiquity, a remarkable piece of Roman work, begun by the emperor Adrian, A.D. 124, on the northern bounds of England, to prevent the incursions of the Picts and Scots.

At first it was made only of turf, strengthened with palisadoes, till the emperor Severus, coming in person into Britain, repaired it, as some say, with solid stone, reaching eighty miles in length, from the Irish to the German sea, through Carlisle and Newcastle; with watch-towers garrisoned, now called *castle-steeds*, at the distance of a mile from each other.

It does not appear with sufficient evidence, that Severus's wall was formed of stone: Bede expressly asserts the contrary, though Spartian intimates that Severus built both a *murus*, *i.e.* a wall of stone, and a *vallum*, or a wall of turf. Bede relates, that "Severus, after several great and difficult engagements, thought it necessary to separate that part of the island, which he had recovered, from the other nations that were unconquered; not with a *murus*, as some think, but with a *vallum*. Now a *murus*," continues he, "is of stone; but a *vallum*, such as they made round a camp, to secure it against the attacks of the enemy, is made of turf, cut regularly out of the ground, and built high above ground, like a wall, with the ditch before it, out of which the turf has been dug; and strong stakes of wood all along the brink." Severus, therefore, drew a great ditch, and built a strong earthen wall, fortified with several turrets from sea to sea. The learned Camden adopts this opinion; and adds, that Severus's wall is expressed by no other word than *vallum*, either in Antoninus or the *Notitia*.

This wall was ruined several times by the Picts, and often repaired by the Romans. At last Aëtius, a Roman general, ordered it to be rebuilt of stone, about the year 420; but the Picts ruining it in the year following, it was thenceforward regarded only as a boundary between the two nations. The wall was eight feet thick, and twelve high, from the ground: it ran on the north side of the rivers Tyne and Irthing, up and down several hills: the tract, or remains of it, are to be seen to this day in many places, both in Cumberland and Northumberland.

The inhabitants of the country pretend, that there was a brazen trumpet, or pipe, so artificially laid in the wall between each castle and tower, that, upon the apprehension of danger at any one place, by the sounding of it, notice might be given to the next, and then to the third, &c., whence it derived the ancient name *cornage;* and in the inside a sort of fortified little town, now called Chester, the foundations of which appear, in some places, in a square form.

PICTS' HOUSE, a name given to the remains of some ancient buildings not uncommon in the Scottish isles, the erection of which is attributed to the Picts. They are composed of large stones uncemented, built up in a conical form, and are of various sizes. Some consist of only a single chamber, with one external wall, others have an outer and inner wall, about two feet distant from each other, the space between being occupied by a winding stair. There is an example at Kirkwall, the form of which is that of a truncated cone, the height being about 14 feet, and its circumference at the base, 384 feet. "It is probable," says a writer on the subject, "that it was surrounded by two walls, but the quantity of rubbish rendered this circumstance difficult to ascertain. Internally, it consists of several cells or apartments, the principal one of which is in the centre, built with large flat stones without cement, the one immediately projecting over that below, so as gradually to contract the space within as the building rises, till the opposite walls meet at the top, when they are bound together by large stones laid across. Six other apartments of a similar form and construction, but of little more than half the dimensions, communicate with the central one, each by a passage of about two feet square, on a level with the floor. There does not appear to have been any contrivance for the admission of light. The earth at the bottom of the cells, as deep as could be dug, was of a dark colour, of a greasy feel, and of a fetid odour, plentifully intermingled with bones both of men, of birds, and of some domestic animals. In one of the apartments, an entire human skeleton in a prone attitude was found, but in the others the bones were not only separated from one another, but most of them divided into small fragments. From their appearance, some have supposed the inhabitants to have been cannibals."

PICTURE (from the Latin *pictura*), an imitation, or representation by lines and colours of any natural object. Such representations are also called *paintings*, from the name of the art by which they are produced; which, being capable of general application, and of great influence upon the mind, has, at all times, since men have cultivated their intellectual powers, been regarded with peculiar interest.

The subject of a picture may be represented in colours, on canvass, wood, or the like; and enclosed in a frame.

Pictures or paintings in oil are preserved by coating them with some transparent or hard substance, as a varnish, in order to secure the colours from the injuries of the air or moisture; and to defend the surfaces from scratches or any damages the painting might receive from slight violence. The substances that have been, or may be used for this purpose, are gum-arabic, dissolved in water, with the addition of sugar or sugar-candy to prevent its cracking; glair or whites of eggs, mixed with a little brandy or spirit of wine, in order to make it work more freely, and a lump of sugar to prevent its cracking; isinglass, used as either of the former, or mixed with a fourth or fifth of its weight of honey or sugar, and varnishes formed of gum resins dissolved in spirit of wine, or oil of turpentine; which last are called *oil-varnishes*.

Paintings in miniature are preserved by plates of glass, or the talc called *isinglass*, placed before them in the frame. Paintings in distemper may be rendered more durable, and preserved from foulness, by varnishing them with hot size, boiled to a strong consistence, in which a fifteenth or twentieth part of honey has been dissolved. Crayons must be preserved in the same manner as paintings in water-colours by plates of glass or isinglass.

When pictures are cut or torn, they may be repaired by laying them on an even board or table, carefully putting together the torn or divided parts with colour laid as a cement, in and over the joint, and keeping them in that situation till the cement is thoroughly dried. The protuberance of the cement may be easily reduced with a penknife, and the repaired part properly coloured so as to correspond with the picture. When part of the cloth is destroyed, a piece of canvass, somewhat bigger than the vacant space, is to be plastered over on the outside of the cloth with white or any other colour, and when it is thoroughly dry, the inequality of the picture in this part is to be filled up with the same matter, properly reduced and coloured.

The art of cleaning pictures and paintings is of great consequence in order to their preservation: in this operation great skill and care are requisite, so that the menstruum used for taking off any foulness may not dissolve the oil in the painting itself, or disorder its colours, and that each sort of varnish with which paintings are coloured may be taken off without injury to the painting. The first and most general substance used for cleaning pictures is water, which will remove any foulness arising from many kinds of glutinous bodies, as sugar, honey, glue, &c., and any varnish of gum-arabic, glair of eggs, or isinglass, without affecting the oil that holds the colours together. Olive oil or butter will dissolve pitch, resin, and other substances of a like kind, without injuring the oil of the painting. Pearl-ashes, dissolved in water, form a proper menstruum for most kinds of matter that foul paintings; but they must be very cautiously used, as they will corrode the oil of the painting, if there be no varnish of the gum resins over it. Soap is of the same nature, and should be cautiously applied, and only to particular spots, that elude all other methods. Spirit of wine will dissolve all the gums and gum resins, except gum arabic, and is therefore very necessary for taking off from pictures varnishes composed of such substances, but it also corrodes the oil of the painting. This is also the case with oil of turpentine, and essence of lemon, spirit of lavender, and rosemary, and other essential oils. With regard to paintings that are varnished with gum-arabic, glair of eggs, or isinglass, the varnish should be taken off when they are to be cleaned. This may be easily distinguished by wetting any part of the painting, which will feel clammy, if varnished with any substance soluble in water. This kind of varnish may be taken off with hot water and a sponge, or by gentle rubbing with a linen cloth dipped in warm water. If paintings, on this trial, appear to be varnished with gum resins, or such substances as cannot be dissolved in water, they may, in some cases, be sufficiently cleaned by a sponge with warm water; and any remaining foulness may be removed by rubbing the painting over with olive oil made warm, or with butter, which should be wiped off with a woollen cloth; and if the picture require farther cleaning, wood-ashes or pearl-ashes may be used in the following manner: take an ounce of pearl-ashes, and dissolve them in a pint of water; or take two pounds of wood-ashes, and stir them well in three quarts of water, once or twice in an hour for half a day. Then pour off the clear fluid, and evaporate it to a quart or three pints; wash the painting well with a sponge dipped in either of these leys, and rub gently any foul spots with a linen cloth till they disappear. If this method fail, recourse must be had, first to spirit of wine, then to oil of turpentine, and if these are ineffectual, the essence of lemons: with either of which the foul spots should be slightly moistened, and the part immediately rubbed gently with a linen cloth. After a little rubbing, if oil of turpentine or essence of lemon has been applied, olive oil should be put upon the spot; and water, if spirit of wine has been used; which should be taken off with a woollen cloth; repeating the operation till the foulness be removed. When paintings appear to have been varnished with those substances that will not dissolve in water, and, after the use of the above means, retain their foulness, the following method will succeed; place the picture or painting in a horizontal situation; and moisten, or rather flood, by means of a sponge, the surface with very strong rectified spirit of wine: keep the painting thus moistened, by adding fresh quantities of the spirit, for some minutes; then flood the whole surface copiously with cold water; wash off the whole without rubbing; and, when the painting is dry, repeat the operation till the whole varnish is taken off.

The art of removing paintings in oil from the cloth or wood on which they are originally done, and transferring them to new grounds of either kinds of substance, is of great use. For those on cloth or canvass, the method is as follows: let the decayed picture be cleansed of all grease that may be on its surface, by rubbing it very gently with crumb of stale bread, and then wiping it with a very fine soft linen cloth. It must then be laid, with the face downwards, on a smooth table covered with fan-paper, or the India-paper: and the cloth on the reverse must be well soaked with boiling water, spread upon it with a sponge, till it appears perfectly soft and pliable. Turn the picture with the face upwards, and, having stretched it evenly on the table, pin it down with nails at the edges. Having melted a quantity of glue and strained it through a flannel, spread part of it, when a little stiffened, on a linen cloth of the size of the painting, and when this is set and dry, lay another coat over it; when this becomes stiff, spread some of the glue, moderately heated, over the face of the picture, and lay over it the linen cloth already prepared in the most even manner, and nail it down to the picture and table. Then expose the whole apparatus to the heat of the sun, in a place where it may be secured from rain, till the glue be perfectly dry and hard; when this is the case, remove the picture and linen cloth from the table. Turn the picture with the face downwards, and let it be stretched and nailed to the table as before; then raise round its edge a border of wax, as in the etching of copper-plates, forming a kind of shallow trough with the surface of the picture; into which pour a proper corroding fluid, as oil of vitriol, aquafortis, or spirit of salt, but the last is to be preferred: dilute either of these with water to such a degree, determined by previous trials, that they may destroy the threads of the original canvass or cloth of the picture, without discolouring it. When the corroding fluid has answered this purpose, drain it off through a passage made at one end of the border of wax, and wash away the remaining part by repeatedly pouring quantities of fresh water on the cloth. The threads of the cloth must be then carefully picked out till the whole be taken away. The reverse surface of the painting, being thus wholly freed from the old cloth, must be well washed with water by means of a sponge, and left to dry. In the mean time prepare a new piece of canvass of the size of the painting; and having spread some hot glue, purified as before, and melted with a little brandy or spirit of wine, over the reverse of the painting, lay the new canvass evenly upon it while the glue is hot, and compress them together with thick plates of lead or flat pieces of polished marble. When the glue is set, remove these weights, let the cloth remain till the glue is become perfectly dry and hard. Then the whole must be again turned with the other side upwards, and the border of wax being replaced, the linen cloth on the face of the painting must be destroyed by means of the corroding fluid; particular care is necessary in this part of the operation, because the face of the painting is defended only by

the coat of glue which cemented the linen cloth to it. The painting must then be freed from the glue by washing it with hot water, spread and rubbed on the surface by a sponge. The painting may afterwards be varnished as a new picture; and if the operation be well conducted, it will be transferred to the new cloth in a perfect state.

When the painting is originally on wood, it must first be detached from the ceiling of the wainscot where it was fixed; and the surface of it covered with a linen cloth, cemented to it by means of glue, as already directed. A proper table being then provided, and overspread with a blanket, or thinner woollen cloth, laid on in several doubles; the painting must be laid upon it with the face downwards, and fixed steady: and the board of wood on which it was done must be planed away, till the shell remains as thin as it can be made, without damaging the paint under it. The process is afterwards the same as that in the case of paintings on canvass, till the painting on wood be in like manner transferred to a cloth or canvass.

PIEDROIT (French) in architecture, a pier or square kind of pillar, part of which is hid within the wall. It only differs from a pilaster in having no regular base and capital, which the other has. *See* PILASTER.

This term is also used for a part of the solid wall annexed to a door or window; comprehending the door-post, chambranle, tableau, leaf, &c.

PIER (from the French *pierre*, a stone) a mass of stone, &c., opposed against the force of the sea, or great river, for the security of ships that lie at harbour in any haven.

PIERS are also used in architecture for a kind of pilasters, or buttresses, raised for support, strength, and sometimes for ornament.

PIERS, *Circular*, also called *massive columns*, are with or without caps, and are frequently seen in Norman architecture.

PIERS OF A BRIDGE, the supports of the arches over the openings, when more than one, not including the supports at the extremities, which are called *abutments*. *See* BRIDGE.

M. Belidor observes, that when the height of the piers is about six feet, and the arches are circular, it is sufficient to make their thickness the sixth part of the width of the arch, and two feet more; but when the arches become of a great span, the thickness of the piers may be reduced to the sixth part; but then the depression of the two feet does not take place at once; that is, in an arch of about forty-eight feet, three inches are taken off for every six feet of increase of the width of the arch. The thickness of the piers supporting elliptic arches is greater than in the former proportion: thus, in an arch of seventy-five feet wide, the thickness of the pier, whose height is about six feet, should be 13.5 when the arch is circular, and fifteen feet when it is elliptical. The same author makes the abutments one sixth part more than the piers of the largest arch; and Mr. Muller has calculated a table, containing the thickness of the piers of bridges.

Rectangular piers are seldom used except in bridges over small rivers; in all others they project from a bridge by a triangular prism, which presents an edge to the stream, in order to divide the water more easily, to prevent the ice from sheltering there, as well as vessels from running foul against them. This edge is terminated by the adjacent surfaces at right angles to each other at Westminster Bridge; but those of the Pont-royal, at Paris, make an acute angle of about 60 degrees. Engineers, however, in their later constructions, make this angle to terminate by two cylindric surfaces, whose bases are arcs of 60 degrees.

PIGGERY, the place where hogs or swine are lodged.

PIG-STY, the name of the place where hogs are kept. Buildings of this kind should always be large and commodious.

PILA, or PILE. *See* PILES.

PILÆ, according to Vitruvius, square blocks placed upon the epistylia, immediately over the columns, to support the timbers of the roof.

PILASTER, (from the French, *pilastre*, or Italian, *pilastro*,) in architecture, a square column, sometimes insulated, but more frequently let into a wall, and only projecting with a fourth or fifth part of its thickness.

The pilaster borrows the name of each order, and has the same proportions, capitals, members, and ornaments, with the columns themselves.

The pilasters in the Attic order are sometimes at equal distances, and sometimes coupled; but this depends on the intercolumniation of the order below. If the Attic order be straight, and immediately over it, it must partake of the same distances, and stand over the column in the lower order.

Pilasters are made, usually, without either swelling or diminution, as broad at top as at bottom: though some of the modern architects, as M. Mansard, &c., diminish them at top, and make them swell in the middle, like columns; particularly when placed behind columns.

Pilasters, M. Perrault observes, like columns, become of different kinds, according to the manner in which they are applied to the wall. Some are wholly detached, and called by Vitruvius *parastatæ;* others have three faces clear out of the wall; others two; and others only one: these are all called by Vitruvius *antæ*.

Insulated pilasters are but rarely found in the antique. The chief use they made of pilasters was at the extremities of porticos, to give the greater strength to the corners.

There are four principal things to be regarded in pilasters; viz., their projecture out of the wall, the diminution, the disposition of the entablature, when it happens to be common to them and to a column, and their flutings and capitals.

1. The projecture of pilasters, which have only one face out of the wall, is to be one-eighth of their breadth; or, at most, not above one-sixth. When they receive imposts against their sides, their projecture may be a quarter of their diameter. They are made to project in different proportions to their diameters, as one-eighth, one-fourth, one-half, and three-fourths; but are never used gracefully quite square, except at angles; and then only in massive buildings, as the portico at St. Paul's, Covent Garden.

2. Pilasters are but seldom diminished, when they have only one face out of the wall. Indeed, where they stand in the same line with columns, and the entablature is continued over both, without any break, the pilasters are to have the same diminution with the columns; that is to say, on the face respecting the column; the sides being left without any diminution. When they are diminished, they have an ill effect; where it becomes necessary to make them correspond with the lines of the columns at top, as is sometimes the case in porticos and returns, then it is better for the architect to make them entirely of the smallest diameter of the column to which they are opposed.

3. Pilasters are sometimes fluted, though the columns they accompany are not so; and, on the other hand, the columns are sometimes fluted, when the pilasters that accompany them are not. The flutings of pilasters are always odd in number, except in half pilasters, meeting at inward angles; where four flutings are made for three, &c.

4. The proportions of the capitals of pilasters are the same as to height with those of columns, but they differ in width, the leaves of the former being much wider; because pilas-

ters, though of equal extent, have only the same number of leaves for their girt, viz., eight. Their usual disposition is to have two in each face in the lower row, and in the upper row one in the middle, and two halves in the angles, in the turns whereof they meet. Add to this, that the rim of the vase, or tambour, is not straight, as the lower part is, but a little circular, and prominent in the middle. In pilasters that support arches, the proportions, Palladio shows, must be regulated by the light they let in; and at angles, by the weight they are to sustain. For which reason, says Sir Henry Wotton, a rustic superficies best becomes them.

Pilaster, *Demi*, or Membretto, a pilaster that supports an arch: it generally stands against a pier, or column.

Pilasters, in ship-building, flat columns, or ornaments, made of deal, fluted or reeded, with moulded caps and bases, and placed in the middle of the munnions, which part the lights of the stern and quarter-galleries; also on the munnions of the bulkheads of the captain's cabin, &c.

Pilaster-Masses, in Gothic architecture, piers of a rectangular plan capped with impost mouldings.

PILE. *See* Piles.

Pile, a word used among architects, for a mass or body of building.

Pile-Driver, a machine for driving piles into the ground, of which there are many kinds; some are worked by a great number of men, who raise a heavy weight to a small height, and then let it fall upon the pile, till, by reiterated blows, they drive it to the required depth. This machine is extremely simple. A long thick plank of wood is fixed up close to the pile, having a mortise through the upper end, in which a pulley is fitted; a rope goes over this to suspend the rammer, which is a large block of hard wood, properly hooped, to prevent it from splitting. In rising and falling, it slides against the face of the plank, and is guided by irons, which are fixed to the ram, and bent round the edges of the plank, in the manner of hooks. The plank, when placed upright, is secured by guy-ropes, in the manner of the mast of a ship; the end of the great rope which suspends the ram, has ten or twelve small ropes spliced into it, for as many men to take hold, and work it by; they raise the ram up two or three feet by pulling the ropes all together, and then letting them go, the ram falls upon the pile-head. When the pile becomes firm enough to cause the ram to rebound, they take care to pull the ropes instantly after the blow, that they may avail themselves of the leap it makes.

This is the simplest form of the machine. Others, instead of a plank, have two upright beams attached together, at such a distance as to leave an opening between them for the reception of a piece of wood which is affixed to the ram, and by this means it is guided. Instead of guy-ropes, these are usually fixed upon a base, consisting of a triangular frame, upon one angle of which the uprights are erected; and from the other two angles, braces arise, inclined so as to reach the uprights at one-half or two-thirds of their height, to steady them. This plan is very convenient for driving piles in corners; but for driving in rows, it is more advantageous to have the uprights fixed at the middle of one side of the triangular base, and have stays from all the three angles. A machine of this kind, with a ram of beech, four feet long and one foot square, may be worked by ten or twelve men, at the rate of twenty-four blows per minute, and fixes the pile very quickly. To estimate the force of the rammer, its weight ought to be multiplied into the velocity it acquires in falling. Thus, if a rammer weighing 500lbs. drop from four feet, it will fall in half a second, and have at the time of percussion a velocity capable of carrying it uniformly eight feet in half a second, without any farther help from gravity; so that we must multiply 500 by 16, or its weight by the number of feet it would fall in a second, and the product, 8,000, gives the momentum of the stroke. If a capstan, pulley, or windlass, be made to raise the rammer to a considerable height, and then, by an easy contrivance, loosen it at once from its hook, the momentum of the stroke will always be as the square root of the height from which the rammer fell.

Notwithstanding the momentum, or force of a body in motion, is as the weight multiplied by the velocity, or simply as its velocity, when the weight is given or constant; yet the effect of the blow will be nearly as the square of that velocity; the effect being the quantity the pile is driven into the ground by the stroke. For the force of the blow, transferred to the pile, being destroyed in some certain definite time by the friction of the part within the earth, which is nearly a constant quantity, and the spaces in constant forces being as the squares of the velocities; therefore, the effects, which are those spaces sunk, are nearly as the square of the velocities, or, which is the same thing, nearly as the heights fallen by the ram or hammer to the head of the pile.

For large works, such as bridges, &c., the piles are driven by a different kind of machine: this has a very heavy iron ram, with mechanical powers, by which it is raised to a very considerable height, and then let fall, instead of continually repeating small blows. These are sometimes worked by horses, or steam-engines.

Figures 1 and 2.—A, A, the uprights, erected on the frame, B, and supported by the braces, C; connected by the cross feet, *a*, at bottom, and the piece, D, at top; in this the pulley, *b*, for the rope, *d*, is fitted. Fillets of iron are fixed withinside the uprights, A, A, and enter grooves made in the edges of the great iron ram, E, which is thereby guided as it rises and falls: F is a piece, called *the follower* (see *Figures* 3 and 4) consisting of a wooden block, sliding between the uprights, and mortised to receive the iron tongs, *e*, which take hold of an eye on the top of the cast-iron ram: the rope is attached to the follower by an iron hoop, *f*, through which the centre pin of the tongs passes. On the base, *a* B, of the machine, an iron frame is bolted, to contain the windlass, G, on which the rope, *d*, winds. On the end of the windlass a cog-wheel, *g*, is fixed, and a pinion upon the axis, *h*, engages its teeth. Motion is given to the spindle, *h*, by the winches, *k*, fixed to each end of it, and the fly-wheel, *l*, regulates its motion, when turned by two men at each handle. The pile is of course included in the space between the two uprights, A, A, before it is driven down; and the ram, being engaged by the tongs, *e*, is drawn up by turning the handle, *k*, till the tails, *n*, of the tongs come to the inclined planes, *m*, *Figure* 1: by these they are closed together, which opening the lower ends, disengages them from the eye of the ram, and it falls upon the head of the pile immediately. The men at the handles shift the spindle, *h*, endwise, which disengages the pinion from the wheel, and then the weight of the follower, F, runs back the windlass, G, and descends till its tongs take hold of the ram, ready to take it up again. The inclined planes, *m*, are not fixed to the uprights, A, A, but are connected together by pieces of wood, which embrace the uprights, and these have holes through them to receive iron bolts, which also pass through the uprights. By this means the inclined planes can be shifted, to set them at any required height, that they may, by discharging the ram at the proper height, give a blow proportioned to the pile to be driven. The tongs are sometimes made with rollers in the ends, *n*, *n*, as shown in *Figure* 12, that they may act more easily in the inclined planes. Other machines have a kind of latch, shown in *Figure* 11, instead of the tongs; in this, *f* represents the iron loop for the rope;

the centre pin of which, passing through the latch, *r s t*, catches the eye of the ram by the hook, *t*, and is discharged by the line *r*, when the men snatch it. The weight, *s*, is to cause the hook to catch; and the loop, *f*, is attached to the wooden follower, which guides it between the uprights.

Machines of this kind are frequently actuated by steam-engines. A pulley, fixed on the end of the spindle, *h*, in place of the handle, *k*, receives an endless rope from some wheel put in motion by the engine; one man then attends it, to throw the spindle endwise at the proper time, to permit the descent of the follower; but we have seen one in which levers, and a connecting rod from the inclined plane, *m*, were used to disengage the spindle the moment after the follower discharges the ram; by adopting these means much expense of labour would be saved, as the steam-engine which is afterwards to be employed in pumping the water out of the coffer-dams, would drive the piles for them and for the foundations.

The piles of the works of Westminster-bridge, whilst it was building, were driven by a horse-machine, invented by Mr. Valoue. A pair of the uprights, such as represented in *Figures* 1 and 2, but thirty feet high, were erected at one end of a frame, which supported a vertical shaft, turned round by the horses, and the framing was of course large enough to admit a circular walk of sufficient size for them to work in, when they drew the ends of arms or levers projecting from the vertical shaft. The whole was erected upon a platform, which was built over a barge in the manner of a deck. The vertical shaft had a wheel or drum upon it, to wind up the rope of the follower, and it was in the construction of this part that the invention lay. A section of the upper part of the vertical shaft and drum is given in *Figure* 8, and a plan in *Figure* 9. Here A is the great upright shaft, or axle, turned by the horses attached to the levers, which are not shown. The cog-wheel, B, turns the pinion, X, having a fly, O, at the top to regulate the motion, and to act against the horses, and keep them from falling, when the ram is disengaged. The drum, C, is loose upon the axle of the shaft, A, but is locked to the wheel, B, by the bolt, Y. On this drum the great rope, H, is wound, one end of it being fixed to the drum, and the other to the follower, passing over proper pulleys. In the follower are contained the tongs, which take hold of the ram, by the staple for drawing it up, as described in *Figure* 2; D is a spiral, or fusee, fixed to the drum, C, on which winds the small rope, T: it goes over a pulley, and has a small counterpoise hung to the end of it, which hinders the follower from accelerating as it goes down to take hold of the ram; for, as the follower tends to acquire velocity in its descent, the line, T, winds downwards upon the fusee on a larger and larger radius, by which means the counterpoise acts stronger and stronger against it; and so allows it to come down with only a moderate and uniform velocity. The bolt, Y, locks the drum to the great wheel, being pushed upwards by the small lever, 3, which passes through a mortise on the shaft, A, and turns upon a pin; the lower end of the bolt is guided by passing through a piece of wood, 6, fixed into the great shaft, and the upper end passes through an arm of the wheel; the lever, 3, has a weight, 4, which always tends to push up the bolt, Y, through the wheel into the drum; G L is the great lever, turning on the centre, *m*, and resting its end, G, upon the forcing bar, 5, which goes down through a hollow in the shaft, A, and bears upon the little lever, 3. The other end of the lever, L, is long enough to reach the uprights, and has there a small rope, extended from its end up to the inclined planes, so that the follower, when drawn to the highest, pulls this rope, and raises the long end, L, of the lever, depressing the other, and forcing the bar, 5. By the horses going round, the great rope, H, is wound about the drum, C, and the ram is drawn up by the tongs in the follower, till they come between the inclined planes, which, by shutting the tongs at the top, open them below, and so discharge the ram, which falls down between the uprights and the pile, and drives it by a few strokes as far into the ground as it can go, or as is desired; after which, the top part is sawed off close to the mud, by an engine for that purpose. Immediately after the ram is discharged, a piece upon the follower takes hold of the rope, which raises the end L, of the lever L G, and causes its end, G, to descend, and press down the forcing-bar, 5, upon the little lever, 3, which, by drawing down the bolt, Y, unlocks the drum C, from the great wheel, B; and then the follower being at liberty, comes down by its own weight to the ram; and the lower ends of the tongs slip over the eye of the ram, the weight of their heads causing them to fall outwards, and fasten upon it: then the weight, 4, pushes up the bolt, Y, into the drum, which locks it to the great wheel, and so the ram is drawn up as before. As the follower comes down, it causes the drum, C, to turn backward, and unwinds the rope from it, while the horses, the great wheel, the pinion X, and the fly, go on with an uninterrupted motion; and as the drum is turning backward, the counterpoise is drawn up by its rope, T, winding upon the spiral fusee, D.

There are several holes in the under side of the drum, and the bolt, Y, always takes the first that it finds, when the drum stops by the falling of the follower upon the ram, till which stoppage the bolt has not time to slip into any of the holes. But the same effect is more certainly produced by a crooked lever, *t*, *Figure* 9, fixed on the framing, R, over the end of the vertical shaft; one end of this has a roller, which is pressed upon by the great rope, H, while the other end holds down the catch, 5, of the forcing bar, but as soon as the great rope slackens, it retires, and gives liberty to the small lever, 3, to push up the bolt. As long as the great rope has a tension upon it, to support the weight of the ram, or follower, the crooked lever is kept in close contact with the forcing-bar, and when that is depressed (to discharge the bolt, Y) by locking over its catch, 5, the crooked lever keeps it down, till the follower touches the ram; the great rope then slackens, and the spring, *v* H, discharges the crooked lever from the catch of the forcing-bar, and gives liberty to the small lever, 4, to push up the great bolt, and to lock the drum to the great wheel, when the ram is drawn up again, as before.

The peculiar advantages of this engine are, that the weight of the ram, or hammer, may be raised with the force of horses instead of men; that when it is raised to a proper height, it readily disengages itself, and falls with the utmost freedom; that the forceps, or tongs, are lowered down speedily, and instantly of themselves again lay hold of the ram, and lift it up; on which account this machine will drive the greatest number of piles in the least time, and with the fewest labourers.

The piles at Westminster bridge, when driven by the above machine till they were quite firm, were cut off, under water, by a machine to a level with the surface of the ground, to build the piers upon. This machine consisted of a framing adapted to fit upon the upper part of the pile, and fixed fast thereto. The lower part of this frame formed guides for the saw, which reciprocated horizontally at a certain depth beneath the top of the pile, and had weights to cause it to advance up to the cut. The saw was put in motion by ropes from each end, which were conducted, over proper pulleys, to two men standing on a float or raft at the surface. After fixing the machine, before the sawing was

begun, the whole machine was suspended by a tackle, which therefore took up the top part of the pile with the machine as soon as it was cut off. This was the invention of Mr. Etheridge, carpenter to the works at Westminster bridge; it was very effective, as the time employed in cutting off a fir pile of 14 or 16 inches square, in 10 feet depth of water, was seldom more, and often less, than a minute and a half. A machine, more convenient than this in its application, and not less effective, was also invented by Mr. Foulds, to whom the Society of Arts presented a gold medal for the invention; see *Figures* 5 and 7, where A A B is the external frame, consisting of four parallel rails, A, framed into two others, B, at right angles, with proper cross pieces to unite them, and inclined to strengthen the whole: within this frame a second, or internal frame, D E, is situated; like the other, it has four parallel pieces, D and E, connected together into one frame by cross pieces; at the top it has two pieces, *a*, *a*, which rest upon the beam, B, and suspend its weight, and on these it is capable of sliding backwards and forwards between B B, always preserving its parallelism, because it is moved by the racks, *d*, *d*, affixed to it, one at top, and the other at the bottom; the pinions for both are fixed on a vertical axis, *e*, supported in the external frame; therefore, by turning the handle, *r*, the internal frame with the saw is advanced to the pile, as at K, *Figure* 6. The saw itself is sustained in a frame, L, *Figure* 7, which fits, in the manner of a sash-frame, between the two beams, D, of the internal frame, and has racks, *f*, *f*, (dotted) behind it, which work in pinions on an axis, *g*, extended across the frame, and by the handle, *y*, it is capable of being drawn up and let down, or detained at any height by a ratchet-wheel and click, *x*; the saw, *m*, is fixed upon a spindle N, supported in bearings on the frame, L, and turned by the handle, R, at the top; the saw is connected with the spindle by a piece of iron, *p*, having a mortise through it for the reception of the spindle, to which it is fastened by a nut beneath; by this means the edge of the saw may be advanced as the work goes on.

In using this machine, the beams, B, are fixed across a barge, which is ballasted till they are horizontal, and the spindle of the saw is therefore vertical in this state; it is moored with her side against the pile, K, to be cut off, as shown by the dotted line, V, *Figure* 6; then, by the rack and pinion, *f g*, the saw is adjusted in height to the level where the pile is to be cut; by the handle, *r*, it is advanced to the pile, K, whilst, by the other handle, R, the saw is kept in continual motion backwards and forwards, till the pile is cut through, and the piece is taken into the barge; it then proceeds to cut off the next by the same means. By this machine, temporary piles, used in coffer-dams, may be cut off level with the bottom, when the work is finished, which is a very superior method to drawing them up out of the ground, as is the usual practice; because this must necessarily make a deep ditch or trench all round the pier or foundation, and tend to loosen the ground.

To draw piles out of the ground when they have been driven fast, requires a very great force. There are different methods of exerting this force: one for drawing them in water, is by having a very strong barge, with a windlass at one end to receive a strong chain, which is passed several times round the head of the pile, and made fast to the barge; two long beams are laid upon the barge, to form a railway for a small waggon to run upon from one end to the other, loaded with stones of several tons weight; when this is wheeled to one end of the barge, it will, of course, depress it in the water, elevating the other; then, in this state, the lowest end of the barge is chained to the pile, by putting a very large bolt through it, and passing a chain round the pile under this bolt a great many times; the carriage is then wheeled to the other end of the barge by a windlass and rope; this tends to raise the end to which the pile is fixed; and when the carriage is so far advanced that it exerts a sufficient power, it will draw up the pile, if the chain is properly fixed; and then the carriage is returned to draw another pile. A plan was adopted at Waterloo Bridge, for drawing the useless piles by one of Mr. Bramah's hydrostatic cylinders. This is represented in *Figure* 10, where A is supposed to be the top of a range of piles forming the coffer-dam, and B the pile to be drawn. A chain, *a*, is made fast to the pile, and carried many times round a large beam, C D, the end, D, of which rests upon a fulcrum, or support, E, consisting of a block, supported on the head of a neighbouring pile, &c. F is a block of two pieces of wood, screwed together in two places, and enclosing between them a cast-iron cylinder, *b*, into which is fitted the piston, or cylinder, *d*, the joining being made tight by a collar of leather; *e* is a small copper pipe, communicating with the cylinder, and also with a small forcing-pump, the piston, *f*, of which, is actuated by the lever, *g h*; the pump is fixed upon the top of a small cistern, *k*, to contain water. Now, by working the lever of the pump, water is injected into the cylinder, *b*, which protrudes the piston, *d*, from it with a force proportioned to the force exerted upon the lever, in the same degree as the areas of the pump to that of the cylinder multiplied by the proportions of the lever, *h*. By this means, the power of one or two men is increased to such a degree as to draw up the largest pile; the copper pipe, *e*, is made to unscrew at several joints, which are provided with leather, to make them tight; by which the pump is separated when the machine is to be removed. As it has no connection with the beam or lever, D, the cylinder is frequently employed in the manner of a hand-jack, for any purposes where enormous weights are to be lifted for a small space. The same figure also shows a very complete way of catching fast hold of the pile, instead of putting a bolt through the pile-head to stop the chain under: it is simply a strong iron ring, *l*, large enough to drop over the pile loosely, and having a strong shank or eye, *m*, projecting from it to run the chain through; when this is drawn, the ring jambs so forcibly upon the wood of the pile as to draw it out of the ground rather than slip off, for it holds faster in proportion to the force.

The theory of Mr. Valoue's engine depends on the following principles, viz.—1. If the resistance of the ground and the masses of the piles be equal, the depths to which they will be driven with a single blow will be as the product of the weight of the ram into the height through which it falls.

2. If the masses of the ram, and heights through which it falls, are both equal, the depths to which the piles will be driven will be in the inverse ratios of the masses of the piles into the superficies of that part of them which is already immersed in the earth.

3. If all these be unequal, the depths will be in a ratio compounded of the direct ratio of the heights through which the ram falls into its mass, and the inverse ratio of the mass of the pile into its immersed superficies.

4. If the weights of the ram be equal, and also the weights of the piles, the depths to which they will be driven will be as the heights through which the ram falls directly, and the immersed superficies of the piles. Or, because the immersed superficies are as the depths through which the piles are already driven into the earth, these depths are simply as the square roots of the heights through which the ram falls.

These principles are founded on the general supposition that the space through which the weight falls is estimated by

the product of its mass into the square of its velocity, or into the height through which it falls.

Hence it is inferred, that the distance through which a pile will be driven by each succeeding blow, will be less and less, as the superficies of that part of the pile which is immersed in the ground increases; and, consequently, that there is a certain depth, beyond which a pile of a given mass and scantling cannot be driven; the mass of the ram and the height through which it falls at first being assigned.

At the close of the year 1843, a new method of sinking piles by atmospheric agency, was patented by Dr. Potts. In this invention the piles are of cast-iron, and hollow, and are lowered by drawing out the sand or soil through the centre by means of an air-pump. The pile is closed at the top with an air-tight cap, through which a pipe passes to a receiver, and from this again another pipe connected with an air-pump. By this means a communication is kept up between the pump and the interior of the pile, and by working the former the air is exhausted from the pile, the sand rises through the interior into the receiver, and the pile gradually sinks into the vacuity so produced. This method of piling has been successfully employed on the Goodwin Sands by the Trinity Board, the piles being driven through the sands to a depth of 75 feet, when they reached a solid foundation. These piles are especially adapted for such situations; they are attended, however, in many instances, with some disadvantage, for by removing the earth occupied by the piles, they lose that firmness of position which is ensured in the old method by its compression. This defect is somewhat compensated for by the injection by hydraulic pressure of certain chemical solutions, and hydraulic cements round the feet of the piles, to consolidate the earth on which they stand, and give them a firm bearing.

The most important of all inventions for this purpose is Nasmyth's steam-hammer, which consists of a steam cylinder, through a steam-tight aperture in the bottom of which the piston-rod passes, having the hammer, or "monkey," suspended from it. The steam admitted at the bottom of the cylinder raises the piston with the monkey attached to it, and in so doing, closes the induction and opens the eduction pipe, which reverses the motion, and the monkey falls with great force upon the head of the pile beneath. The following description of the action of this machine is extracted from a contemporary, and has especial reference to its employment at Morice Town, Devon.

"There are two features which most remarkably distinguish this important invention from all pile-driving machines. These consist, in the first place, in the direct manner in which the elastic power of the steam is employed to lift up the mass of iron by whose fall on the head of the pile it is driven into the ground; secondly, in the peculiar manner in which the block of iron and its guide-case and cylinder are made to sit, as it were, on the shoulders of the pile, so as to predispose and assist it in its descent into the ground. In this manner, the entire dead-weight of this part of the apparatus is rendered available, and made to act in a most important degree as a portion of the pile-driving agency, and as the entire part of the apparatus follows the pile down, it never ceases for one instant to yield a most important assistance towards the attainment of the desired object. The energy and rapidity of the blows, which are dealt out on the head of the pile at the rate of upwards of 70 per minute, is such, that, assisted by the dead-weight of the apparatus sitting upon the shoulders of the pile, it is seen to sink into the ground in steps varying from 6 feet to 3 inches per stroke,—the whole operation of driving the pile, 60 feet in length, occupying little more than from two and a half to four minutes,—in fact, such is the ease and rapidity with which these enormous piles are driven into the ground by these powerful machines, when compared with the old system, that the spectator is as much inclined to laugh at the ridiculous contrast, as to be astonished at its vast powers, and the perfect control under which it is placed. The whole movements are governed by one handle, regulating the supply of steam from the boiler to the cylinder and piston, which yields the requisite rising and falling motion of the monkey or hammer that drives the pile. We are particularly attracted by the simple and efficient contrivance which Mr. Nasmyth has adopted for carrying the steam from the boiler to the cylinder on the head of the pile, namely, by wrought-iron jointed pipes, which fold up in the most beautiful manner in a succession of joints or lengths, so as to accommodate the length of steam at all the various heights of the apparatus, which, having to descend through a perpendicular space of upwards of 50 feet in following down the sinking, double up or fold together in the most perfect yet simple manner. The same boiler which supplies the steam to the actual pile-driving apparatus, likewise supplies steam to a small engine, which is employed to give the requisite locomotive action to the whole apparatus in either direction, so as to cause it to move from pile to pile. The same small engine hoists and pitches the piles in the most perfect manner; also raises the pile-driving apparatus to the head of the highest pile, some of which are 66 feet in height, and places it on the shoulders of the pile with the utmost ease and exactness. Some idea of the performance may be formed when we state, that it drives a pile of 66 feet in length in four minutes, while, with the ordinary machines, upwards of 15 or 20 hours would be occupied in doing the same work, to say nothing of the entire absence of all damage to the head of the pile, which, in the case of the employment of Mr. Nasmyth's machine, is not in the slightest degree injured; while in driving such a pile by the ordinary machine, the head of the pile is so shattered by the repetition of its destructive and ineffectual blows, as to require to be cut off and reheaded several times during the operation. Practical pile-drivers will have some idea of the remarkable superiority in the action of Mr. Nasmyth's machine, when we inform them, that the iron hoop hitherto employed to preserve the head of the pile from being split into matches, is, in the steam pile-driver, entirely dispensed with, and the heads of the piles, after driving, bear scarcely any evidence of force having been applied to them."

Pile-planks, are planks whose ends are sharpened, to drive into any canal or water, close to each other, in order to form a dam, by which the water may be stopped and discharged. *See* Piles.

Pile-sheeting, the same with dovetail piling.

Piles, in hydraulic architecture, are beams of timber, or stakes of wood, driven firmly into the ground, for various purposes; as, for forming a foundation for buildings, piers of bridges, &c., in which cases they are driven quite down into the ground, or are cut off level with its surface, with a view of obtaining a solid bearing for the weight of the intended superstructure.

Amsterdam, and some other cities, are wholly built upon piles. The stoppage of the breach in the banks of the Thames at Dagenham, was effected by dovetail piles; that is, by piles mortised into each other by a dovetail joint.

Piles are not employed for foundations, unless the ground is suspected to be unsound, or when the weight to be borne is exceedingly great. They make the foundation solid, by reaching deep into the earth, down to a more substantial stratum than that of the surface. Indeed, the manner of

fixing the piles, by driving them by repeated blows of a powerful machine till they will go no farther, ensures that they come to a good bearing.

Piles are also used for making the faces of wharfs, banks of rivers, piers for the sea, &c. For these purposes they are driven in rows, but only a sufficient depth in the earth to make them stand firm, and support the planking or framing which is fixed against them. These piles are usually driven rather in an inclined position. For temporary defence against the water, in laying the foundation of bridges, &c., piles are always required; they are employed in different ways to form an enclosure, or water-tight wall, called a coffer-dam, round the area where the work is to be laid, and from which space the water is drawn by pumps. This is the most difficult of all kinds of piling; because it must stand a great height above the ground, have sufficient strength to resist the pressure of water, and be perfectly close and tight. In navigable rivers detached piles are driven, and very firmly fixed, to mark the enclosures where barges are to lie, and to fender off others from them, as well as to moor them to.

Piles are in general formed of square timber, tapering if the tree happens to be so, cut to a sharp point at one end, and shod with iron to enter the ground. The other end is bound by a strong iron hoop, to prevent the pile-head from splitting by the violence of the blows which drive it down. When they are to be driven quite below ground, small trees, if sufficiently straight, may be used without squaring; but for coffer-dams, square piles are always used, except for filling up a row between such square piles. When they are to touch each other, flat ones, called *pile-planks*, are used; they are three or four inches thick, according to the depth of water, and have grooves formed in their adjacent edges, to receive tongues or slips of wood, which make the joints quite tight. This method is termed *sheet-piling*. To enclose an area for a coffer-dam, two rows, or walls of piles, are usually driven one within the other, at a distance usually equal to the depth of water where they are driven; or, if the current is rapid, once and a half. The space between these is filled with clay, so as to form a mound or rampart of that material, defended on the outside and inside by wooden walls of piles. To make these walls, large square piles are first driven, at a distance of ten or twelve feet asunder, in the line of the intended range of the dam; horizontal tie-beams are then extended from one pile to the next, on the inside, and sometimes on the outside also, each tie being notched into the piles, so that its outer edge is in a line with the inside of the groove for the plank-piles, which are to be driven down to fill up the spaces between the piles, and will be guided by these ties to stand exactly vertical, and in a straight line. The first plank-piles are fixed adjacent to the main piles, and thus they are continued from both ends of the interval, till the planks meet in the centre, where the last plank is inserted, and, being formed rather wedge-like, it makes all the rest tight. The pile-planks are cut inclined, or wedge-like, on one side only, to form the point, by which means the point is in the line of one of the edges of the plank. When a plank pile is to be driven adjacent to another, this edge is applied to the one already fixed, and then, as it is driven, the inclined or wedge-like edge entering the ground, causes the pile to approach, and press very close to its neighbour; and it is chiefly by this means they are made to fit water-tight. The fillets are made by spiking a ledge or ruler of wood fast upon the edge of one plank, and a groove of corresponding depth and width is ploughed in the edge of the adjacent plank to receive it.

The square *gauge* or *guide* piles, as they are termed, are usually composed of whole timbers from twelve to fourteen inches scantling, but the plank piles, or sheet-piling, as well as the horizontal ties or *walings* of half-timbers, being of the same width, but only half the thickness of the square piles.

Piles of cast-iron were first employed by Mr. Mathews in the formation of Bridlington harbour, in which work he made use of sheets of iron 8 or 9 feet long by 2 feet in width, and half an inch thick, so contrived at the sides, that each pile should form a dovetail joint with the adjoining one. Mr. Ewart, however, was the first who brought this kind of piling into general notice; he took out a patent for his invention in 1822. These piles consisted of plates of iron from 10 to 15 feet in length, 14½ inches in width, and 1½ inch in thickness; they have a flanch running down the centre, and one at each extremity, turned off at an acute angle with the face. To connect these together, he made use of a smaller pile only 6 inches wide, but having a flanch at each side corresponding with those at the sides of the larger plate, so as to form a dovetail joint with them. Where a greater length of piling was required, a method of lengthening them was adopted, by placing one above another, and securing the horizontal joints by means of dovetail cramps.

Mr. Ewart's piles have been extensively adopted, especially by Mr. Hartley, in the Liverpool docks, who has employed them successfully, and speaks favourably of their employment in such works as coffer-dams. He states, that considerable care is required in keeping the piles in a vertical position, as they are apt to shrink every blow, and drive slanting. They require to be driven between two heavy balks of timber to keep them in a straight line, as they expose very little section to the blow of the ram, and are so sharp, that they are easily driven out of a right line. There is another very necessary precaution to be taken, which is the keeping the fall of the ram in the same line as the pile; otherwise, the ram descending on the pile, and not striking it fairly, all parts equally, the chances are, that, if in a pretty stiff stratum, the head breaks off in shivers, and the pile must be drawn, which is sometimes no easy matter.

Mr. Mylne has also employed those piles to a considerable extent, especially in a large coffer-dam opposite the New River Company's establishment at Broken Wharf, where he succeeded in driving the larger and smaller piles or cramps simultaneously, the usual practice being to drive them separately.

A work on a much larger scale was constructed of the same material by Mr. Cubitt at the sea entrance of the Norwich and Lowestoft navigation; but the form of the piles was, in this instance, of a somewhat different description. The wall consisted exclusively of sheet piling without any guide-piles whatever, each pile being 30 feet long, 18 inches broad, and 1½ inch thick, having a deep flanch in the centre, without any dovetail or other jointing at the sides; the perfectness of the joints depending entirely upon close and accurate driving. As some assistance to the driving, a pair of strong wrought-iron cheeks, projecting two or three inches beyond the edge of the pile, were riveted on to the lower end, which served as a guide or groove to keep the piles flush. The entire length of wharfing thus constructed was about 2,000 feet.

Another work of importance is that of Walker and Burgess at the Brunswick Wharf, in front of the East India Docks at Blackwall, of which we copy the following description, as given by Mr. Borthwick in the Transactions of the Institution of Civil Engineers.

"The first operation was to dig a trench two yards deep in the intended line, and this was immediately followed by

the driving of the timber guide-piles. The deepening in front, which, to give the required depth of 10 feet at low water, was as much as 12 feet, was not done until near the conclusion of the work; to have effected it in the first instance would, without any countervailing advantage except some saving in the driving, have been attended with the double expense of removing the ground forming the original bottom between the old and new lines of wharfing, and afterwards refilling the void so left by a material that would require time to make it of equal solidity; and even if this had been otherwise, such an attempt would have endangered the old wall, or rather would have been fatal to it. The permanent piling was next begun, the main piles being driven first at intervals of seven feet, and the intermediate spaces or bays then filled in, working always from right to left, towards which the drafts of the sheet-piles were pointed. The ground is a coarse gravel, with a stratum of the hard Blackwall rock occurring in places, and some trouble was occasionally experienced from its tendency to turn the piles from the proper direction; but due attention being paid to the form of the points, the drawing was, on the whole, effected pretty regularly, but few of the bays requiring closing piles made specially for them, so that the work may be said to be nearly iron and iron from end to end; at the same time, the vertical joints of the piling being all covered, as will be noticed presently, any slight imperfection, in this respect, is no serious detriment to the work as a whole.

"The main piles are in two pieces, the lower end of the upper one being formed so as to fit into a socket on the top of the under length, and the joining made good by means of a strong screw-bolt; the only object of this was to insure a supply of truer castings, and lessen the difficulty of transporting such unwieldy masses from Northumberland and Staffordshire to London. Each sheet-pile is secured at the top by two bolts to the uppermost wale of the woodwork behind, and the edge of the end-ones of each bay, it will be observed, pass behind the adjoining main pile, while the other joints are overlapped by the bosses with which all the sheet-piles, except the closers, are furnished on one side. Besides adding to the perfection and security of the works, by breaking the joints, so that the water, if it penetrate, (as, even with the best pile-driving, it will,) cannot draw the backing from its place, these projections appear to me to relieve the appearance of the otherwise too uniform space, and a like effect is produced by the horizontal fillets on the lower edges of the plates above, which also mask the joints. These plates filling up the space over the sheet-piling, are bolted to the main piles and to each other, in the manner shown, and the joints stopped with iron cement. Where the mooring-rings come, the plates are cast concave, with a hole perforated in the middle, to allow a bolt to pass through, and this bolt is secured, as well as the land-ties, from the main piles to the old wharf, which was not otherwise disturbed, or to needle-piles driven adjoining to it. The backing consists of a concrete of lime and gravel, in the proportion of about one to ten, extending down to the solid bottom. The coping, with the water-channel in its rear, is of Devonshire granite; the water is conveyed from the channel at intervals by pipes extending from gratings in the bottom, in a slanting line, to the lowermost plate, and discharging themselves immediately above the sheet-piling. The main piles were originally proposed to be hollow, but this was given up on further consideration of the uncertainty of procuring sound castings of the intended form, and of the greater liability to break afterwards from a blow sideways.

"The solid form was therefore adopted, according to which the lower lengths weighed about 28 cwt., and that this was not too much, was shown by the circumstance of several of the piles, particularly the early ones, breaking in the testing, or driving, and showing in the fracture the danger of even a slight defect. The greater care subsequently taken at the foundry, and probably also greater experience in driving, made accidents of this kind of rare occurrence in the later stages of the work; and it may be mentioned as no bad proof of the care of all parties, that of upward of 600 piles, including both descriptions, only 16 broke in driving—7 being of one sort, and 9 of the other: the failure was in five cases attributed to strains in driving, and to imperfections of casting in the other eleven. The sheet-piles, which bear a considerable resemblance in their general outline to those used at Downes wharf ten years before, were proposed to be an inch thick, but it was found necessary to increase this dimension, and some of them was as much as $1\frac{1}{4}$ inch; the average, however, was not above $1\frac{1}{8}$ inch, and weight of each pile 17 cwt.; the length of the wharf is about 720 feet, and the whole weight of iron used, upwards of 900 tons.

"The crab engine was employed invariably, the heads of the piles being covered with a slip of three-quarter inch elm, to distribute the force of the blow equally over the iron, and so prevent jarring. The monkeys used, weighed from 13 to 15 cwt. each, and it was found necessary to limit the fall to a height of 3 feet 6 inches, and sometimes less; when the resistance proved more than usually great, the pile showed a tendency to turn from its straightforward course. The driving throughout was very hard, more especially at the west end, where the sheet-piles in four bays, could not be forced to the full depth, the space above being in two of them made up with two plates in height, and in the other two admitting only one instead of three, as in the rest of the work. Driving was the only means resorted to, or indeed practicable, in the gravelly soil that prevailed. Had the bottom been clay, or other similar substance, the plan of boring, to receive the points, might probably have been partially adopted in the main piles with advantage; but I should say, certainly not to the extent of depending mainly upon it for getting the piles home to their places."

Piles similar to the above have been employed in many situations, differing only in matters of detail, which we do not think it requisite more fully to describe.

Piling of cast-iron seems to be very well adapted for cofferdams, wharf-walls, embankments, and such works, but is not to be substituted for timber when employed for foundations, for unless based upon a very firm stratum, they are not so secure against sinking when heavily loaded; nor, on account of their small sectional area, do they compress and consolidate the soil through which they pass to the same extent as timber pilings, and this compression greatly assists in forming a solid foundation for the superstructure. Another disadvantage which attends the use of this material, is the deterioration which it undergoes by the action of water upon it, and especially of sea-water.

The screw-pile introduced by Mr. Mitchell, is admirably adapted for loose and moveable strata, and has been found very useful in situations where all other means had failed. This pile consists of a spindle of the required length, with a broad cast-iron plate or disc, in a spiral or helical form, attached to the lower end, so as to form a screw by means of which the pile is secured in the ground. The following account of them is taken from a summary of a paper read by Mr. A. Mitchell, and published in a cotemporary.

"The origin of the screw-pile was the screw-mooring, which was designed for the purpose of obtaining, for an especial purpose, a greater holding power than was possessed by either the ordinary pile, or any of the usual mooring

anchors or blocks, of however large dimensions. It was proved by experiment, that if a screw with a broad spiral flange were fixed upon a spindle, and forcibly propelled by rotary motion to a certain depth into the ground, an enormous force would be required to abstract it by direct tension, and that the power employed must be sufficient to drag up a mass of the form of a frustum of a cone reversed, the base being at the surface of the ground, and the section of the apex being equal to the diameter of the screw. The extent of the resisting mass must of course depend upon the natural tenacity of the soil; even in this reasoning it must be evident that a vertical force was calculated upon, but as practically that seldom or never occurred, the angle of tension and the curve of the buoy-cable again gave the moorings greater power. This was found to be correct in practice, and the applications of these moorings became very extensive. An arrangement was made with the port of Newcastle-on-Tyne, by which, for the sum of £2,500, the right of fixing the moorings in the Tyne was given; and Mr. Brookes, the engineer, showed that last year, (1847,) whilst in the neighbouring port damage was done to the shipping to the extent of nearly £30,000, no injury was sustained in the Tyne, entirely owing to the sound holding of Mitchell's screw-pile moorings.

"It naturally occurred to Mr. Mitchell, that the same means of resistance to downward pressure might be used, and he proposed to apply it for the foundations of light-houses, beacons, and other structures, which for maritime purposes it might be desirable to place upon sand and mud banks, where hitherto it had been considered impracticable to place any permanent edifices. In the year 1838, a plan for a structure of this nature for a lighthouse on the Maplin Sand, at the mouth of the Thames, was laid before the corporation of the Trinity House, supported by the opinion of Mr. James Walker, their engineer. The 9 iron piles, 5 inches in diameter, with screws 4 feet in diameter, were accordingly driven 22 feet deep into the mud, and, with proper precaution, they were allowed to stand for two years, before any edifice was placed upon them. The lighthouse was subsequently constructed, and, as was testified by Mr. Walker, had stood perfectly until the present time (March, 1848"). The plan of the piling in this instance was octagonal, one pile being driven in each of the angles of the octagon, and another in the centre, making in all 9 piles, which were fixed in their places in 9 consecutive days, being screwed to a depth of 22 feet in the bank. The piles were made of malleable iron, 5 inches in diameter, and 26 feet long, with a cast-iron screw, 4 feet in diameter, screwed to the foot.

"Another lighthouse was erected to point out the entrance to the harbour of Fleetwood on Wyre; and under the advice of Captain Denham, R.N., the screw-piles were adopted. The spot fixed on was the point of a bank of loose sand about two miles from the shore. Screw-iron piles, with screws of 3 feet in diameter, were forced about 16 feet into the bank, and upon them timber-supports, 48 feet in vertical height, were fixed, to carry the house and lantern. This structure was completed in six months, and it was said had never required any repairs to the present time," (March, 1848.)

Another method of piling was invented by Dr. Potts, but as this is connected more especially with PILE DRIVING, it has been described under that article, and does not demand any further observation in this place.

PILLAGE, among builders, a word sometimes used for a square pillar, standing behind a column to bear up the arches; having a round base and capital, as a pillar has.

PILLAR (from the Italian *piliere*, or French *pillier*) a kind of irregular column, round and insulate; but deviating from the proportions of a just column.

Pillars are always either too massive or too slender for regular architecture. In effect, pillars are not restrained to any rules; their parts and proportions are arbitrary. Such, for instance, are the pillars which support Gothic vaults, and other buildings, &c.

A square pillar is a massive work, called also *pier*, or *piedroit*, serving to support arches, &c.

A butting-pillar is a butment, or body of masonry, raised to prop, or sustain, the thrust of a vault, arch, or other work.

It seems not impossible for stone to be cast into the shape of pillars. We find mention made in the *Philosophical Transactions* (No. 481, p. 328, in *note*,) of two pillars of stone at Fontevraud, in France, each about 60 feet high, all of one solid piece, which are said to have been run. Pillars of stone were anciently erected as sepulchral monuments, near the highways; and also in memory of some victory. We find traces of this custom in Cornwall and Wales, where these pillars are often found, and called *meinigwir*, a stone for play, perhaps in memory of funeral games; and sometimes *llech*, that is, *tabula saxea*.

Pompey's pillar is a famous monument of antiquity, constructed of red granite, and situated on a rock, about a mile without the walls of Alexandria, in Egypt. By the mensuration of Edward Wortley Montagu, Esq., the capital of the pillar, which is Corinthian, with palm-leaves, and not indented, is 9 feet 7 inches high; the shaft 66 feet $1\frac{1}{4}$ inch; the base 5 feet $9\frac{3}{4}$ inches; the pedestals 10 feet $5\frac{1}{2}$ inches; the height from the ground 92 feet: though Dr. Pococke, by the shadow, determined the whole height to be 114 feet; and its diameter 9 feet and an inch. It is perfectly well polished, and only a little shivered on the eastern side. Nothing can equal the majesty of this monument: seen from a distance, it overtops the town, and serves as a signal for vessels. Approaching it near, it produces, says Savary, an astonishment mixed with awe. One can never be tired with admiring the beauty of the capital, the length of the shaft, nor the extraordinary simplicity of the pedestal. This prodigious mass stands, as on a pivot, on a reversed obelisk; and was erected, as many have supposed, either by Pompey, or to his honour. But as no mention is made of it by Strabo, Diodorus Siculus, or any other ancient writers, Mr. Montagu concludes that it was not known before the time of Vespasian, and that it was erected to his honour. In proof of this opinion, he found within the circumference of the pillar a medal of Vespasian, in fine order.

Savary, on the authority of Abu'lfeda, who calls it "the pillar of Severus," ascribes it to this emperor; alleging, that he visited Egypt, gave a senate to Alexandria, and deserved well of its inhabitants. Accordingly, it is said that this column was a mark of their gratitude. The Greek inscription, half effaced, which is visible on the west side when the sun shines upon it, was legible, without doubt, in the time of Abu'lfeda, and preserved the name of Severus. Nor is this the only monument erected to him by the gratitude of the Alexandrians. In the midst of the ruins of Antinoë, built by Adrian, is seen a magnificent pillar, the inscription on which is still remaining, dedicated to Alexander Severus.

Denon has given a drawing of this pillar, with the marked dimensions of its various parts: he makes its whole height a fraction more than 92 feet; and the height of the shaft, which is of a single piece, 63 feet $1\frac{3}{10}$ inch. It acquired, as this author says, the name of Pompey's pillar in the 15th century. A monument, as he supposes, had been raised by

Pompey at Alexandria, but it had disappeared, and was thought to be recovered in this pillar or column, which has since been converted into a trophy erected to the memory of Septimius Severus. It is, however, placed on the ruins of the ancient city; and in the time of Septimius Severus, the city of the Ptolemys was not in a ruinous state. To support this column by a solid foundation, an obelisk has been sunk in the earth, on which is placed a very clumsy pedestal, having a fine shaft, and surmounted by a Corinthian capital of bad workmanship. If the shaft of this column, continues Denon, separating it from the pedestal and the capital, once belonged to an ancient edifice, it is an evidence of its magnificence, and of the skill with which it was executed. It ought, therefore, to be said, that what is called Pompey's pillar is a fine column, and not a fine monument; and that a column is not a monument. The earth about the foundation of this pillar having been cleared away by time, two fragments of an obelisk, of white marble, the only monument of that substance seen by Denon in Egypt, have been added to the original base, to render it more solid. After having observed that the column, entitled Pompey's pillar, is very chaste both in style and execution; that the pedestal and capital are not formed of the same granite as the shaft; that their workmanship is heavy, and appears to be merely a rough draft; and that the foundations, made up of fragments, indicate a modern construction; it may be concluded, says our author, that this monument is not antique; and that it might have been erected either in the time of the Greek emperors, or of the caliphs: since, if the capital and pedestal are well enough wrought to belong to the former of these periods, they are not so perfect but that art may have reached so far in the latter.

PINION, an arbor, or spindle, in the body of which are several notches to catch the teeth of a wheel that serves to turn it round. Or a pinion is a lesser wheel, which plays in the teeth of a larger.

PINNACLE, (from the Latin, *pinna*, or *pinnaculum*,) the top or roof of a house, terminating in a point. This kind of roof, among the ancients, was appropriated to temples; their ordinary roofs being all flat, or made in the platform-way. It was from the pinnacle that the form of the pediment took its rise.

But the term is more generally applied to the slender and spire-like terminations in Gothic architecture, which rise from the top of buttresses, roofs, and other parts of an edifice. They form a very beautiful enrichment to the more delicate carvings in screens, shrines, and other works of a decorative character.

PINNING, the fastening of tiles together with pins of heart-of-oak; for the covering of a house, &c.

Pinning-up, the process of driving the wedges in underpinning the upper work, so as to make a good bearing upon the work below.

PIPE, a tube for the conveyance of water, gas, steam, soil, &c., made of various materials, as lead, iron, earthenware, &c.

PISCINA, (from the Latin, *pisces*, *fish*,) a large bason in an open public place or square, where the Roman youth learned to swim; it was surrounded with a high wall, to prevent the casting of filth into it.

Piscina, was also used for the square bason in the middle of a bath.

Piscina, or Probatica, (from the Greek, πραβατον, *sheep*,) a pool or reservoir of water, near the court of Solomon's temple; here the cattle, destined for sacrifice, were washed. By this piscina it was, that our Saviour wrought the miraculous cure of the paralytic. Davilier observes, there are still remaining five arches of the portico, and part of the bason of this piscina.

Piscina, or Lavatory, among the Turks, a large bason placed in the middle of the court of a mosque, or under the porticos that encompass it. Its form is usually a long square. It is built of stone or marble, furnished with a great number of cocks, wherein the Mussulmans wash themselves before they offer their prayers.

Piscina, the perforated stone usually found in a niche on the right-hand side of the altar, in our ancient churches and chapels, into which the water used in washing the hands of the officiating priests, and other sacred ablutions, was cast.

Piscinas were almost always placed on the south side of the altar, and usually in the south wall, but sometimes in the east wall. They were of various degrees of ornamentation, some being very plain, and others elaborately enriched; not unfrequently we find a double niche, and sometimes a single niche, with a sink and shelf above it, which is supposed to have been used as a credence-table.

PISE, a term applied to a peculiar mode of forming buildings of different kinds, but more especially those designed for farm-purposes, with some sort of stiff earthy materials of a loamy quality. It is an easy, economical, and convenient method, which had its rise on the continent, and has been had recourse to in different parts of this kingdom, as in Bedfordshire, Lancashire, &c.

The difference between this, and the common mud-walling, consists in the earth being pressed in moulds, by which it is rendered much more compact, and is not subject to crack so readily in the drying.

PIT OF A THEATRE, all that space between the amphitheatre, or galleries, and the theatre, or stage; called, by the ancients, *orchestra:* and by the French, *parterre*. This being the most commodious part, it was here the Roman senate was placed. It has its name, *pit*, in Latin, *cavea*, from its being sunk below the level of the stage.

PITCH, in building, the vertical angle of a roof, or the proportion between the height and span; as, when the height is one-fourth, one-third, or one-half of the breadth of the building. If the height is one-half of the breadth, the inclination of the planes, forming the vertical angle, is a right angle.

In former times, the vertical angles of roofs were made so very acute, that the length of the rafter was three-fourths of the breadth of the building; but, in the present day, when the coverings are mostly of slate, mansions and dwelling-houses have the height of the roof one-fourth or one-third of that breadth; though in some country-places, the practice still continues of making the rafters three-fourths of the breadth of the building, which they call *true-pitch;* but when the length of the rafters is equal to the breadth of the building, the pitch is denominated *Gothic*.

PITCHING-PIECE, in staircasing an horizontal piece of timber, having one of its ends wedged into the wall, at the top of a flight of steps, to support the upper ends of the rough-strings.

PIX, the casket in which the consecrated host was preserved for the use of the sick. It was usually of metal, placed upon the altar under a canopy, but was sometimes made in the form of a dove, and suspended over the altar.

PLACARD, the decoration of the door of an apartment, which is sometimes a cornice supported by consoles.

PLACE-BRICKS, were originally kiln-burnt red bricks of a full size, now entirely disused in the metropolis; but in lieu of them, the soft insufficiently burnt bricks from the outside of the clamps are called, by way of distinction from stock or hard-burnt bricks, *place-bricks*. These are of a foul

red colour, and will easily break or crush to pieces. The particular manner in which place-bricks were formerly made, was by dipping the mould in water before the clay was put in; which made the outer surfaces, when burnt, very coarse and hard. *See* BRICK.

PLAFOND, or PLATFOND, (French) the ceiling of a room, whether it be flat or arched; lined with laths and plaster, and sometimes also enriched with paintings, &c. *See* CEILING.

PLAFOND is also more particularly used for the bottom of the projecture of the larmier of the cornice; called also *the soffit.*

PLAIN ANGLE, an angle contained under two lines, or surfaces, so called in contradistinction to a *solid angle.*

PLAIN FIGURE, that of which the surface is a plane, bounded by one or more lines.

PLAIN TILES, or PLANE TILES, such as are intended to have their surfaces planes.

PLAIN TRIANGLE, a triangle included under three right lines, or surfaces; in opposition to a *spherical*, and a *mixed triangle.*

PLAIN TRIGONOMETRY, the doctrine of plain triangles, their measures, proportions, &c.

PLAN, (French) a representation of something drawn on a plane. Such are maps, charts, and inchnographies.

PLAN, in architecture, is particularly used for a draught of a building; such as it appears, or is intended to appear, on the ground; showing the extent, division, and distribution of its area into apartments, rooms, passages, &c.

To render plans intelligible, it is usual to distinguish the massives with a black wash. The projectures on the ground are drawn in full lines, and those supposed over them, in dotted lines. The augmentations, or alterations, to be made are distinguished by a colour different from what is already built; and the tints of each plan are made lighter as the stories are raised. In large buildings, it is usual to have three several plans for the first three stories.

The plan is the first device, or sketch, the architect makes; it is also called the *ground plot*, *platform*, and *ichnography*, of the building.

PLAN, *Geometrical*, that in which the solid and vacant parts are represented in their natural proportion.

PLAN, *Perspective*, one that is conducted and exhibited by degradations, or diminutions, according to the rules of perspective.

PLAN, *Raised*, that where the elevation, or upright, is shown, upon the geometrical plan, so as to hide the distribution. *See* ELEVATION.

PLAN OF A BASTION, in the military art, the same with the *face of the bastion.*

PLAN, in ship-building, the section of a ship, as designed upon paper, previously to the actual building, of which three are the chief, viz., the plan of elevation or sheer-plan; the horizontal or half-breadth-plan; the plan of projection or body-plan; these three compose the *sheer-draught.* But it must be observed, that the extreme length, breadth, and height must be determined; by which the three plans aforesaid may be delineated. These may be called *the outlines*, and the several parts contained within them may be delineated so as to answer the intended purpose; and likewise have a distinct view of the whole design, so that any inconveniencies attending such a disposition may be easily remedied, and the true dimensions of every particular may then be had upon the draught. The delineating of a ship upon a plan is called *drawing*, and the representation is called *draught.*

PLANCERE, the soffit of the corona of a cornice.

PLANE, (from the Latin, *planus*,) a tool used by artificers who work in wood, to produce straight, flat, and even surfaces upon that material.

Almost all trades which fabricate articles of wood, employ planes at times; but as joiners make a greater use of these tools than any others, they are usually considered as joiners' and carpenters' tools. Planes have been of late years used by some artists to produce flat surfaces in metals. A plane operates to cut off a thin chip, or shaving, from the wood on which it is applied, by the sharp edge of a steel cutter, or broad chisel, called, very improperly, the *plane iron:* this is fixed in a hole made through a wooden block, called the *plane stock*, and the edge of the iron projects in a very small degree through the lower side of the stock, called the *face of the plane;* the surface of which face is made a perfectly true plane.

The iron is fixed in an inclined position in the hole through the stock, by means of a *wedge* driven in before it, to jamb it fast in the hole, which being wider than the thickness of the iron, leaves an aperture before the iron, called the *mouth* of the plane; this is very narrow where it opens in the lower side, or face, but grows wider as it rises up through the stock: the wedge is also cut forked, to allow more room for the shavings which the plane-iron cuts, to pass up before it through the mouth. When a plane of this kind is applied with its face upon the surface of a piece of wood, and pressed down upon it whilst it is moved forwards, the edge of the iron penetrates the wood to the depth which it projects through the face, and removes a shaving of that thickness, the whole breadth of the edge of the iron; the shaving turning up before the iron, passing through the mouth, and escaping. The inclination of the iron makes it cut easily; and if the iron is *set fine*, that is, if the edge projects but very little beyond the face, it will remove very thin shavings, and produce a flat and smooth surface: on the other hand, if it is *set rank*, that is, with a considerable projection, it will cut away very fast, producing a flat, though rough, surface, and quickly reducing the wood to its intended thickness: if the wood has an irregular surface, it soon reduces it to a plane, because the face, being flat, will not suffer the edge of the iron to descend into the hollow places, but removes all the eminences it passes over till they are reduced to one level.

This is a general description of several kinds of planes, which are all known by different names, from their various dimensions and purposes.

Joiners use the *jack plane*, the *long plane*, *trying plane*, *shooting plane*, or *jointer*, and the *smoothing plane;* all which they denominate *bench planes*, because the wood they are used upon is generally laid on the work-bench. They have also the *straight block*, for straightening short edges; *rebating planes*, for forming rebates; others for the same use, are called the *moving fillister*, *sash fillister*, and *side-rebating plane.* The *plough* is a narrow plane, provided with an apparatus to guide it, in moving straight forward, to plow a groove or trench at any required distance from the edge of a board, or other piece of wood, and to any depth or width. The *dado grooving plane* is also for forming grooves.

There are several other tools, which, having an iron fitted into a stock, are called *planes*, because they cut in the same manner, though, in strictness, they are not planes, for they do not make plane surfaces; these are *moulding planes*, with faces and cutting edges curved, to produce all the varieties of ornamental mouldings, and which are known by the names of *snipe's-bills side snipe's-bills*, *beads*, *hollows. and rounds*, *ovolos*, and *ogees.* The varieties and different sizes of these form a vast number with which every complete joiner is furnished. It is impos-

sible to describe the terms applied to these tools without figures, as they are arbitrary, though generally known among workmen. The faces of all these planes are straight in the direction of their length, but a section across the face is the impression or reverse of the moulding they are intended to make, and the edge of the iron is curved to correspond with this curve when in its place, though in reality it is a very different figure, because it is inclined to the face of the plane at an angle of about forty-five degrees. Another distinction between these and the bench planes is that their mouths do not open so as to discharge the shaving through the stock at the top thereof, but the wedge completely fills the hole, and the shaving passes out sideways through a hole for that purpose: in some, these apertures are on the right, and in others on the left side; in the first case, the shaving is said, by the workmen, to be thrown on the bench, that is, upon the right side of the plane; but when the orifice of discharge is on the left, and consequently the shaven thrown upon the left, then the plane is said to throw the shaving off the bench. The *compass plane* is used by coach-makers, cabinet-makers, &c.; it is made with a convex face, formed to an arc of a circle in the direction of its length, and it therefore forms the concave surface of a cylinder. The *fork-staff plane* is straight in the direction of its length, but its face is made concave in its breadth, to the arc of a small cylinder; the edge of the iron is of course curved in the same manner, and it planes cylindrical surfaces. Coopers also employ long and heavy planes to form the edges of the staves of barrels, these are mounted in an inclined position on legs like a stool, with their faces upwards, and the stave is drawn backwards and forwards upon them.

Planes are so necessary for all kinds of work, that any who intend to work in wood, should understand the structure, and the manner of using them. The *jack plane* is used for taking off the rough and prominent parts from the surface of the wood, and reducing it nearly to the intended thickness, in coarse shavings, or slices. The stock of this plane is about seventeen inches in length, three inches high, and three and a half inches broad; all the sides are straight, and at right angles to each other: the mouth is cut through the solid of the stock to receive the iron, and hold it at such an elevation, as to make an angle of forty-five degrees with the face of the plane; the iron is a thin metal plate, one side consisting of iron, the other of steel; the lower end of the iron is ground to an acute angle off the iron side, forming a sloping part called *the basil of the iron*, so as to bring the steel side to a sharp edge: the wedge which fixes the iron in its place is let into two grooves of the same form, on the sides of the opening or mouth: two sides of the wedge are parallel, and it is forked, or cut away in the middle, leaving the sides like two prongs, to fill the lower part of these grooves; this allows the shaving to pass up, without obstruction, before the wedge: for the mouth or opening through the stock must be uninterrupted from the face to the top, and must be no wider on the face of the plane, than is sufficient for the thickest shaving to pass with ease; and as the shaving is discharged at the upper side of the plane, the opening through it must expand or increase from the face to the top, so as to prevent the shavings from sticking therein. A handle, called the *tote*, is fixed to the upper side of the stock, immediately behind the iron; it is formed to the shape of the hand, and the direction of the motion, so as to produce the most power in pushing the plane forward.

A workman in using the jack-plane, lays the piece of wood on the bench parallel to its sides, with the farther end lodged against the bench-hook; then laying the fore part of the plane upon the hind end of the wood, with the right hand he takes the handle, and pressing with his left upon the fore-end, thrusts the plane forward in the direction of the fibre of the wood and length of the plane, until he has extended the stroke the whole length of his arm, the shaving being discharged at the orifice; he then draws back the plane, and repeats the operation in the next adjacent rough part, proceeding in this manner until he has removed the rough parts throughout the whole breadth. He then steps forward the distance of the length he has planed, and operates upon another length in the same manner, proceeding this way by steps until the whole length is gone over and rough-planed. To do this is very easy; but a workman will not make good progress, nor do clean work, unless he has first adjusted his tool properly for the work. The methods for doing this are nearly the same for all planes. The first care is to obtain a sharp cutting-edge to the iron; if it requires grinding on the grindstone, the carpenter places his two thumbs under the iron, and the fingers of both hands above, laying the basil side to the grindstone, and holding it to the angle he intends it shall make with the steel side of it, keeping it steady while the stone revolves; and pressing the iron to the stone with his fingers; in order to prevent the stone from wearing the edge of the iron into irregularities, he moves it alternately from edge to edge of the stone, with so much pressure on the different parts, as will reduce it to the required bevel, and make the edge straight.

The basil being brought to a proper angle, and the edge to a regular and slight curvature, the roughness occasioned by the gritty particles of the stone is taken away by rubbing its edge on a smooth flat stone, or turkey-stone, sprinkled with olive-oil on its surface. As the basil is generally ground, to give a more acute angle than the edge of the iron would stand, for the quicker dispatch of wetting it, the face of the iron is inclined nearer to the perpendicular, while it is rubbed backwards and forwards with the same inclination throughout. Every time the iron becomes dull or blunt by use, the sharpening is produced by grinding on the rubber-stone, or flat grindstone, or on a turkey-stone; but, in repeating this, after the edge gets thick, it requires so much time to bring it up to an edge, that recourse must be had to the grindstone. The iron being thus sharpened, must be fixed in the plane by its wedge: the projection of the cutting-edge must be just so much beyond the face of the plane, as that the workman may be able to work it freely in the act of planing, and must be regulated by the stuff to be wrought, whether it be hard or soft, cross-grained or curling; so that a man may be able to perform the most work, or reduce the substance most in a given time. If the stuff is good and clean-grained, it is evident that a considerable projection may be allowed, as a thicker shaving may be taken. The extreme ends of the edge of the iron must never enter the wood, as this not only retards the progress of working, but chokes and prevents the regular discharge of the shavings at the orifice of the plane. The projection of the cutting-edge is called *iron*, and the plane is said to have more or less iron, as the projection is greater or less; when there is too much iron, the workman knocks with a hammer on the fore end of the top of the stock, and the blows will loosen the wedge, and raise the iron in a certain degree, after which the head of the wedge must be knocked down to fix it again. When the workman has occasion to take out the iron to sharpen it, he strikes the fore end of the top of the stock smartly with the hammer, which loosens both the wedge and the iron.

All the other bench-planes are adjusted in the same manner, and indeed do not differ, except in dimensions, as we shall explain, from the jack-plane. Of late years a great improvement has been introduced in the irons of planes, to cause

them to cut smooth; these are called *double-ironed;* they were at first only used in the finest shooting planes, but the advantages have been found so great, particularly in planing bad wood, that they have become general for all sorts of planes. The double iron consists of a second iron, with a reversed basil, screwed against the front side of the iron, so that its edge lies against the iron at a very small distance from, and parallel to, the cutting-edge; and applying closely to the steel side of the iron; it forms an inclined plane, which turns the shaving over immediately after it is separated or cut by the edge, and thus it prevents the iron from splitting the shaving deeper down than it will afterwards cut, and therefore leaving a rough or torn surface. This second iron is called *the cover of the iron;* and the basil of its edge, instead of being ground flat, as that of the iron, is rounding; the screw, which binds the cover upon the iron, passes through a slit in the cover, and thus admits of its edge being adjusted at any required distance from the cutting-edges of the iron, and this distance depends altogether on the nature of the wood the plane is to be worked upon. If the stuff is clean-grained, the edge of the cover may be set at a considerable distance, because the difficulty of pushing the plane forwards becomes greater, as the edge of the cover is nearer the edge of the iron, and the contrary when more remote: this is occasioned by the edge of the cover turning the shaving over, immediately upon its being cut up. The *trying-plane* is usually twenty-two inches long, three inches and three-quarters broad on the face, and three inches and one-eighth in height; it does not differ from the jack-plane, except in having a double handle, adapted for greater force; in use, it succeeds the operation of the jack-plane, to straighten the wood, and remove the ridges left by the former; it is set with less iron, and cuts a finer shaving: the mouth is also much narrower. When it is used upon a long piece of work, the workman takes every shaving the whole length, by stepping forwards, instead of stopping at arm's length, as with the jack-plane. The shaving of this plane, though finer, is so much broader than that of the jack, that it requires as much force to push it forwards.

The *long plane* is set very fine, for finishing work which is to be very straight; it is twenty-six inches long, three and a half broad, and three inches and one-eighth in height.

The *shooting plane*, or *jointer*, is the longest, and most correct plane used; it is employed after all the others, chiefly in shooting the straight-edges of boards which are to be jointed together; it is generally made two feet and a half long, three inches and three quarters broad, and three and a half high; it is used like the others, but with great care to move it steadily from one end of the work to the other, without pressing it down, as that might spring the plane, or the work, and cause the iron to cut when the work was something hollow, whereas the object is to make a perfectly straight edge. The face of this plane must be kept quite true, and therefore it is a great object to make it of a fine piece of clean-grained, hard beech, well seasoned, that it may not warp, or vary, by the weather.

The *smoothing plane* is very short, without any handle, and its sides are curved, so that it very much resembles a coffin; it is seven inches and a half long, three broad at the mouth, and two inches and three quarters in height; it is used for finishing work when put together, and to give the greatest degree of smoothness to the wood, for which purpose it is set with as fine an edge as possible.

Rebating planes are used for cutting out rebates: these are a kind of semi-grooves upon the edge of a board, or other piece of wood, formed by cutting down or reducing a small part of the breadth of the board to half, more or less, of the general thickness: by this means, if a rebate be cut on the upper side of one board, and the lower side of another, the two may be made to overlap each other, without making them any thicker at the joint. Rebates are also used for ornamenting mouldings, and many other purposes in joiners' work. The planes for cutting them are of different kinds, some having the cutting-edge at the side of the iron and of the stock, others at the bottom edge of the iron and the face of the stock, and others cutting in both these directions; the former, being used to smooth the side of the rebate, are therefore called *side-rebating planes;* whilst the others are used for smoothing the bottom. There is also a third sort, called *fillisters*, used for sinking, or cutting away the edge of a piece of wood to form the rebate, leaving it for the others to smooth the surfaces when cut. The rebate planes are about nine inches and a half long, and of various widths upon the face, from half an inch to an inch and three quarters, in all cases they have the mouth and the edge of the iron coming out at one edge of the face, and the side of the iron also exposed at one of the upright sides of the stock, whether it is formed with a cutting-edge there or not; this exposed side is either on the right or left, and they are named accordingly. In all cases, they throw the shaving out on the side, instead of the top of the stock. The cutting-edges and mouths are generally situated obliquely across the face, instead of being at right angles to the length of the plane, as in others.

The *moving fillister* is a rebating plane, which has a ruler of wood, called the *fence*, fixed upon its face by screws, in the direction of its length, and exactly parallel to the edge of the face; it therefore covers part of the length of the cutting-edge, and can be fixed at any required distance from the edge, to leave more or less of the cutting-edge exposed, and this quantity will be the breadth of the rebate it will cut; because when it is used, the edge of the fence is applied against the edge of the piece to be rebated, and thus gauges the breadth its iron shall cut away. The cutting-edge of this plane is not situated at right angles to the length of the stock, but has an obliquity of about forty-five degrees, the exposed side of the iron being more forwards than the other. By this obliquity, when the plane is worked it has a tendency or drift to run farther into the breadth of the wood, but as the fence, silding against the edge, prevents this, the drift always keeps the fence in contact with the edge, without the attention of the workmen; it also causes the iron to cut the bottom of the rebate smoother, particularly in a transverse direction to the fibres, or where the stuff is cross-grained, than could otherwise be done, when the steel face of the iron is perpendicular to the vertical sides of the plane. The principal use is, however, to contribute with the form of the cavity to throw the shaving into a cylindrical form, and thereby make it issue from one side of the plane. The iron is what is called *shouldered*, that is, the lower part, or shoulder, where the edge is, has double the width of the upper part, which is received into the mortise, and jambed fast by the wedge. It is the edge of this wide part only which is exposed at the side of the stock. Besides this principal iron, there is another small iron, called the *tooth*, which precedes the other, to scratch or cut a deep crack at the width of the rebate, thus making the shavings, which the iron cuts up from the bottom, separate sideways from the rest of the wood. This tooth is inserted in a vertical mortise through the stock, between the fore end of the stock and the iron. The lower end of this little iron is ground with a basil on the inside, so as to bring the bottom of the narrow side of the iron to a very convex

edge; it is fastened by a wedge passing down before it in the mortise in the stock. The use of this tooth is principally for cutting the wood transversely when wrought across the fibres, and, by this means, it not only cuts the vertical side of the rebate quite smooth, but prevents the iron from ragging or tearing the stuff. The iron between the fence and the edge of the face of the plane, must project the whole breadth of the unconvered part of the face, otherwise the wood of the plane will bear it up, and prevent the plane sinking as it cuts away the rebate, and the edge of the tooth, or little iron, should stand out a little farther on the side of the plane than the iron. The depth of the rebate, which this plane will cut, is regulated by a stop fixed on the outside of the plane, at the intended height, above the level of the face: then, when the plane has penetrated or sunk the intended depth of the rebate, the stop comes to bear upon the solid of the wood beyond the rebate, and bears it off from cutting any longer. The stop is a piece of brass, which moves in a vertical groove made in the side of the stock, between the iron and the fore end of the plane; in this it is moved up and down by a screw, which is inserted in a vertical perforation from the top of the plane to the groove, and passing through a part projecting from the stop into the groove: the upper part of the screw is formed to a thumb-nut, to turn it round by, and it is so confined by proper collars, that it can neither move up nor down; but being turned, the inclination of the threads will rise or fall according to the direction in which the thumb-screw is turned, and cause the stop to move up and down in the groove on the side of the plane, thus regulating it at pleasure to the depth to which the rebate is required to be sunk.

In grinding and fixing the iron of this plane, it is necessary that the cutting-edge of the iron should stand equally prominent in all parts out of the face, otherwise the plane cannot make shavings of an equal thickness; and, consequently, instead of keeping the vertical position, will, as it proceeds, become deeper on the side on which the shavings are thickest, and then the part cut away will not be regular, for the bottom of the rebate will not be parallel to the upper surface of the wood, and the side which ought to have been vertical, will be a kind of a ragged curved surface, formed by as many gradations or steps in the depth, as the number of shavings.

The *sash fillister* differs, in several particulars, from the moving fillister: the breadth of the iron is something more than the whole breadth of the sole, so that the extremities of the cutting-edge are, in a small degree, without the vertical sides of the stock: the fence is adapted to be moved to a considerable distance, not being fixed as in the moving fillister, by screws upon the face, but sustained by two bars fixed fast to it, which pass through the two vertical sides of the stock, at right-angles to the sides, fitting tight in the two holes through which they pass: these bars are made rounding upon the upper side, and flat on the lower side: at the point, where they are united to the fence, they have thicker parts, or shoulders, projecting downwards, because it is necessary to have the fence fixed on a lower level than the face of the plane; the ends of the bars are ferruled, to prevent their splitting when the ends are struck with the mallet, in order to move them in the holes through the stock, and this brings the fence either nearer, or more remote from the stock, as may be wanted; and to fix it fast, when so adjusted, two small tapering pieces of wood, called *keys*, are inserted into two small wedge-like mortises, cut at the sides of the mortises, in which the bars pass through the stem; these wedges being drawn in, they will stick fast, and press against the bars, keeping them fast at all points, and thereby regulate the distance of the fence from the vertical side of the stock. This plane is generally employed to rebate narrow pieces of wood, such as sash frames; and the fence is applied against the opposite edge of the wood to that on which the rebate is to be formed.

The *plough* is a plane with a very narrow face, made of iron, fixed beneath a wooden stock, and projecting down from the wood of the stock, the edge of the iron being the full width, or rather more, than the face; it is guided by a fence with bars, like the fillister above described, to make, or plough out a groove of the width of the iron, and at any required distance from the edge of the wood; it has also a similar stop to regulate the depth it cuts to. Joiners, cabinet-makers, &c., in plaining thin, or valuable woods for veneering, &c., sometimes use fluted irons, having teeth in their edge; and a plane, thus mounted, is called a *toothing plane;* these irons apply to the stocks of different planes. *See* Tools.

Plane, in geometry, a surface which will everywhere coincide with a straight line.

Wolfius defines a plane, "a surface, from every point of whose perimeter, a right line may be drawn to every other point in the same."

As the right line is the shortest extent from one point to another, so is a plane the shortest extension between one line and another.

Planes are frequently used in astronomy, &c., for imaginary surfaces, supposed to cut, and pass through, solid bodies; and on this foundation is constructed the whole doctrine of conic sections.

When a plane cuts a cone parallel to one of its sides, it makes a parabola; when it cuts the cone parallel to its base, it makes a circle. *See* Circle and Parabola.

The sphere is wholly explained by planes, imagined to cut the celestial luminaries, and to fill the areas or circumferences of the orbits; and they are differently inclined to each other; and by us, the inhabitants of the earth, the plane of whose orbit is the plane of the ecliptic, their inclination is estimated with regard to this plane.

Plane, *Geometrical*, in perspective, a plane parallel to the horizon, whereon the object to be delineated is supposed to be placed. This plane is usually at right angles with the perspective plane. *See* Perspective.

Plane, *Horizontal*, a plane passing through the spectator's eye, parallel to the horizon, cutting the perspective plane in a straight line, called *the horizontal line.*

This, according to Brook Taylor's definitions of perspective, may be called *the vanishing plane of the horizon.* *See* Perspective.

Plane, *Inclined*, one that makes an oblique angle with a horizontal plane.

Plane, *Objective*, any plane face, or side, of an original object to be represented in perspective.

Plane, *Perspective*, a plane pellucid surface, ordinarily perpendicular to the horizon, and placed between the spectator's eye and the object he views; through which the optic rays, emitted from the several points of the object, are supposed to pass to the eye, and, in their passage, to leave marks that represent them on the said plane.

Plane, *Vertical*, a plane passing through the spectator's eye, perpendicular to the geometrical plane, and at right angles to the perspective plane. *See* Perspective.

Plane Table, a rectangular board, with a plane face, for finding the position and distance of a point, or of any number of points, situated in the same plane. By this means the plan of horizontal objects, whether straight or crooked, can very easily be ascertained by only one distance being given.

PLANIMETRY, (from Latin, *planus*, plain, and Greek, *μετρεω*, to measure,) that part of geometry which considers lines and plane figures; without reference to heights or depths.

Planimetry is particularly restrained to the mensuration of planes or surfaces, in opposition to *stereometry*, or the mensuration of solids.

Planimetry, or the art of measuring the surfaces and planes of bodies, is performed with the squares of long measures, as square inches, square feet, square yards, square perches, &c.; that is, by squares whose sides are an inch, a foot, a yard, a perch, &c.; so that the area or contents of any surface is said to be found, when we know how many such square inches, feet, yards, &c., it contains.

PLANING MACHINE, a machine used to diminish the great manual labour of planing the surfaces of planks and boards of wood: in strictness, those alone should be termed planing machines, which reduce the surface of the wood to a true and smooth plane, by means of planes, or instruments of a similar nature, though actuated by the power of machinery instead of the strength of a man's arm; but custom has denominated those machines which cut flat surfaces in a different manner from planes, by the same name.

These machines are of modern invention; the first, we believe, was projected by General Bentham, who obtained a patent for it in 1791. It consisted of a plane, to be put in motion by means of a crank turned by a mill, to give it a reciprocating motion; or, on a smaller scale, it might be worked by hand in the usual manner, but the plane was so formed as to require none of the skill and attention necessary in the ordinary method of operating. The plane is made the full width of the boards intended to be planed, and on each side of it fillets, or cheeks, are fixed, which project beneath the face of the plane just as much as the thickness the board is to be reduced to: these cheeks, therefore, guide the plane sideways in passing along the board, and gauge it in thickness; because, when the board is reduced to the quantity that the cheeks are beneath the surface of the plane, the cheeks rest upon the bench, or surface, on which the board lies, and bear off the plane, so that it can cut no longer. The plane is kept down by its own weight, which is increased, when necessary, by loading it with weights, and these are contrived to be capable of shifting their position from one end of the plane to the other during the time it is making the stroke; because, at first, the pressure is required at the fore end to enter the cut, but, at the conclusion, it must be greatest at the hinder end, to prevent the fore end tripping down the instant it leaves the board. By another contrivance, the plane is caused to rise up sufficiently to clear the cutting edge from the wood when the plane is on its return. It is by a piece, which acts as a handle to the plane, and to which the power is applied, that it is fixed in the manner of a lever upon an axis extending across the width of the plane, and carrying at each side thereof a short lever, provided with rollers in their extremities; the handle projects upwards from the plane, which being forced forwards by it, assumes an inclined position, as do also the short levers, and their rollers then rise above the cheeks of the plane; but when the plane is drawn back, its handle is first drawn back into an erect position, and the levers moving with it, their rollers project beneath the cheeks of the plane, and raise it off the bench, the plane being in its return borne by them.

The bench for supporting the board during the operation, was also of a peculiar construction, in order to confine the work steady upon it. In cases when the boards to be planed are winding or irregular on the lower side, so that they cannot lie flat upon the bench, it is provided with two sides, which can be brought to close upon the edges of the board, and hold it steady between them, being furnished with one or more rows of flat teeth, to penetrate the wood and retain it; these sides are contrived to rise or fall upon the bench, to accommodate the different thicknesses of the boards. When a very thin board is to be planed, it might be liable to spring up to the iron, so as to be reduced even after the plane came to rest with its cheeks upon the bench; to avoid this, the edges of the board are to be held by the sides to the bench before-mentioned, but as it would still be liable to spring up in the middle part, heavy rollers, or rollers loaded with weights, are fitted in apertures made in the plane as near as possible to the cutting-edge, and these will keep the board down close upon the bench. For planing pieces of greater thickness at one end than the other, the cheeks of the plane are to be borne upon rulers of wood laid on the bench on each side, the wood being as much thicker at one end as the board is intended to be thinner at that end; therefore, when the plane has reduced the wood, the cheeks come to bear upon these rulers, and cause it to move not parallel to the bench, but inclined, according as they are thicker at one end than the other; in like manner, by using them of different thicknesses at the different sides, the boards may be made feather-edged.

Mr. Bramah invented a planing machine, which he used very advantageously for planing all kinds of timber flat, at a very trifling expense. In 1802, he took out a patent for the invention, which he describes, in his specification, to consist in the following particulars. "The cutting tools employed to reduce the wood, instead of being worked by hand, are to be fixed on frames, some of which are moved in a rotatory direction round an upright shaft, and others have a shaft lying in a horizontal position, like a common lathe. In other instances, the tools are fixed on frames, which slide in stationed grooves to be driven also by machinery. The principal points on which the merits of the invention rest are, 1. The materials to be wrought are made to slide in contact with the tool, instead of the tool being carried by the hand over the work in the usual way. 2. The tool is made to travel across the work in a square or oblique direction, except in cases where it may be necessary to fix the tool in an immovable station, and cause the work to fall in contact with it by a motion. 3. Instead of common tools, bent knives, spoke-shaves, or deep cutting gouges, are used for cutting off the roughest parts, and planes of various shapes and constructions, as the work may require, are applied to follow the former in succession, under the same operation, and which latter I call *finishers*. 4. These are fixed on frames which move in cases, like those on which the saws are fixed in a sawing-mill; and in other instances, these frames are fixed on a rotatory upright shaft turning on a step, and carrying the frame round in a direction similar to the upper mill-stone for grinding corn; and sometimes the frames turn on a horizontal shaft, resembling the mandrel of a common turning lathe. The different planes, tools, &c., are fixed in the frames, so as to fall successively in contact with the wood or other materials to be cut, so that the cutter or tool calculated to take the rough and prominent part, operates first, and those that follow must be so regulated as to reduce the material down to the line intended for the surface. These cutter frames must also have the property of being regulated by a screw or otherwise, so as to approach nearer the work, or recede, at pleasure, in order that a deeper or shallower cut may be taken at discretion, or that the machine may repeat its action, without raising or depressing the material on which they act. 5. When an upright shaft is used the pivot is to turn in oil, and it may be raised or

depressed at pleasure, by means of a greater or less quantity of the said fluid being confined between the end of the shaft and the bottom of the step. 6. The materials to be cut must be firmly fixed on a frame, similar to those in sawing-mills, on which the timber is carried to the saws. These frames must be moved in a steady progressive manner as the cutter frame turns round, either by the same power which moves the latter, or otherwise, as may be found to answer best in practice. 7. The motion of the cutter frames must be under the control of a regulator, so that the velocity of the tool, in passing over the work, may be made quicker or slower, as such work may respectively require, to cause the cutter to act properly to the best advantage." For this purpose, Mr. Bramah proposes to use what he calls *an universal regulator of velocity*, and which he describes as follows: "I take any number of cog-wheels, of different diameters, with teeth that will exactly fit each other through the whole; suppose ten, or any other number, but, for an example, say ten, the smallest of which shall not exceed one inch in diameter, and the largest suppose ten inches in diameter, and all the rest to mount by regular gradations in their diameters, from one to ten. I fix these ten wheels, fast and immovable, on an axis perfectly true, so as to form a cone of wheels; I then take ten other wheels, exactly the same in all respects as the former, and fix them on another axis, also perfectly true, and the wheels in perfect gradation also; but these latter wheels I do not fix fast on their axes, like the former, but leave them all loose, so as to turn on the said axes, contrary to the former, which are all fixed. All these latter wheels I have the power of locking, by a pin or otherwise, so that I can, at discretion, lock or unite any single wheel at pleasure to the axis. I then place the two axes parallel to each other, with the wheels which form the two cones, as above described, in reverse position, so that the large wheel at one end of the cone may lock its teeth into the smallest one in the cone opposite, and likewise *vice versa*. Then suppose the axis, on which the wheels are permanently fixed, to be turned about, all the wheels on the other axis will be carried round with velocities correspondent to their diameters and those of the former, but their axis will not move. Then lock the largest wheel on the loose axis, and, by turning about the fastened axis, as before, it must take ten revolutions, while the opposite wheel performs but one; then by unlocking the largest wheel, and locking the smallest one at the contrary end of the cone in its stead, and turning as before, the fastened axis will then turn the opposite ten times, while itself only revolves once. Thus the axes or shafts of these cones, or conical combinations of wheels, may turn each other reciprocally, as one to ten, and ten to one, which collectively produces a change in velocity, under a uniform action of the *primum mobile*, as ten to a hundred; for when the small wheel on the loose axis is locked, and the fast one makes ten revolutions, the former will make one hundred; and by adding to the number of those wheels and extending the cones, which may be done *ad infinitum*, velocities may be likewise infinitely varied by this simple contrivance: A may turn B with a speed equal to thousands or millions of times its own motion; and by changing a pin and locking a different wheel, as above described, B will turn A in the same proportion, and their power will be transferred to each other, in proportion as their velocities, reciprocally. Here is a universal regulator at once for both power and velocity. In some instances I produce a like effect, by the same necessary number of wheels made to correspond in conical order, but, instead of being all constantly mounted on the axes or shafts, as above described, they will reciprocally be changed from one axis to the other, in single pairs, to match according to the speed or power wanted, just as in the former instance. This method will have, in all respects, the same effect, but not so convenient as when the wheels are all fixed."

In 1803, Mr. Bevans obtained a patent for a machine for planing, (or *sticking*, as the joiners term it,) all kinds of mouldings or rebates, and ploughing grooves, as well as forming flat surfaces of small breadth, which it does with very little labour: in this machine, the operations are performed by the planes commonly used for similar purposes, with only such alterations as are necessary to adapt them to the machinery by which they are put in motion with mechanical power instead of human labour; they are to be used either singly, or combined together in any number, according to the width of the boards to be worked at once, and the nature of the work to be done, so as to plane up, at one operation, such moulding as joiners work up, by using several planes successively for the different parts; this is effected by a kind of frame, or box, which admits of fixing any number of planes in it, side by side, and at any distance asunder, to form the compound moulding required. The work is fixed fast on a bench, and the box of planes is made to pass over it, in the direction of its length, by a connecting rod communicating at one end with the box or frame containing the planes, and, at the other end, with machinery capable of affording a reciprocating motion.

This machinery consists of a crank, whose radius must be nearly half the length of the required stroke, and must be regulated accordingly: this regulation is effected by the arm of the crank passing through a mortise in a strong box, fixed on an axis, and sliding in the said box to any required length, where it must be fixed by strong screws, the axis being turned by manual exertion, by horses, steam, water or any other power, and having its motion regulated by a fly-wheel.

The planes are loaded, to keep them in contact with their work, by a long beam of wood, set up on end upon the sides of the box, and connected therewith by being divided into two cheeks, which, at the lower sides, are formed to an arc of a circle, and united to the box by chains, in the same manner as the beams of steam-engines are connected with their piston-rods. The upper part of the beam is made to pass always through one point, by sliding between friction-wheels, or otherwise, in a tube hung on two pivots, perpendicularly over the centre of the work, and at such heights as may be most convenient for the length of the stroke required: the connecting-rod, from the crank before mentioned, is jointed to the upright beam, near its lower end, and by this means the motion is given to the box of planes, the chains and arches at the bottom allowing it, in all positions, to preserve the plane horizontal. To guide the box of planes in a rectilinear motion, and also to bear them off when the plank has been reduced to the depth required, fences are used, which are irons sliding perpendicularly in tubes or sockets, in the box or frame, and clipping a tongue, or ruler, fixed in the direction of the required stroke, in the frame supporting the bench.

PLANISPHERE, (from Latin, *planus*, and Greek, *σφαιρα*,) a projection of the sphere, and the several circles thereof, on a plane; as upon paper, or the like. In this sense, maps of the heavens and the earth, in which are exhibited the meridians, and other circles of the sphere, are called planispheres. *See* PROJECTION.

In all planispheres, the eye is supposed to be a point, viewing all the circles of the sphere, and referring them to

a plane on which the sphere is, as it were, flattened. This plane is called the *plane of the projection.*

A perspective plane is only a plane of projection placed between the eye and the object, so as to contain all the points which the several rays, drawn from the object to the eye, impress thereon. But in planispheres or astrolabes, the plane of the projection is placed beyond the object, which is the sphere. The plane of the projection is always one of the circles of the sphere.

Among the infinite number of planispheres which the different planes of projection, and the different positions of the eye, would furnish, there are two or three that have been preferred to the rest. Such are that of Ptolemy, where the plane of projection is parallel to the equator; that of Gemma Frisius, where the plane of projection is the colure, or solstitial meridian, and the eye the pole of the meridian; that of John de Royas, a Spaniard, whose plane of projection is a meridian, and the eye placed in the axis of that meridian, at an infinite distance. This last is called the *analemma.* The common defect of all these projections is, that they distort and alter the figure of the constellations, so that it is not easy to compare them with the heavens; and that the degrees in some places are so small, that they afford no room for operation.

All these faults M. de la Hire provided against in a new projection, or planisphere; where it is proposed the eye shall be so placed, as that the divisions of the circles projected shall be sensibly equal in every part of the instrument. The plane of his projection is that of a meridian.

PLANK, (from the French, *planche*) a general name for all timber, excepting fir, which is from one inch and a half to four inches thick: if of less dimensions it is called *a board.*

Plank-Hook, a pole with an iron hook at its end, with which navigators shift their runs, or wheeling-planks, as occasion requires.

Plank-Sheers, or, Plan-Sheers, the pieces of plank wrought horizontally over the heads of the timbers of the forecastle, quarter-deck, and round-house, for the purpose of covering the top of the side; hence, sometimes called *covering-boards.*

PLANTING, in architecture, denotes the laying the first courses of stone on the foundation, according to the measures, with all the exactness possible.

PLASTER, (from πλαζω) in building, a composition of lime, sometimes with hair, sometimes with sand, &c. to parget or cover the nudities of a building.

Plaster of Paris, a fossile stone, serving many purposes in building; and used likewise in sculpture, to mould and make statues, basso-relievos, and other decorations in architecture.

It is dug out of quarries, in several parts of the neighbourhood of Paris; whence its name. The finest is that of Montmartre. *See* Gypsum.

Plaster of Paris, amongst our workmen, is of two kinds, viz., *crude*, or in the stone, and *burnt*, or beaten.

The *crude* is the native plaster, as it comes out of the quarry; in which state it is used as shards in the foundations of buildings.

The *burnt* plaster is a preparation of the former, by calcining it like lime in a kiln or furnace, and then beating it into powder, and diluting and working it. In this state it is used as mortar, or cement, in building.

This, when well sifted, and reduced into an impalpable powder, is used also to make figures, and other works of sculpture; and is, besides, of some use in taking out spots of grease, &c. in stuffs and silks.

The method of representing a face truly in plaster of Paris is this: the person, whose figure is designed to be taken, is laid on his back, with any convenient thing to keep off the hair. Into each nostril is conveyed a conical piece of stiff paper, open at both ends, to allow respiration. These tubes, being anointed with oil, are supportod by the hand of an assistant; then the face is lightly oiled over, and the eyes being kept shut, alabaster fresh calcined, and tempered to a thinnish consistence with water, is, by spoonfuls, nimbly thrown all over the face, till it lies near the thickness of an inch. This matter grows sensibly hot, and, in about a quarter of an hour, hardens into a kind of stony concretion; which, being gently taken off, represents, on its concave surface, the minutest parts of the original face. In this a head of good clay may be moulded, and therein the eyes are to be opened, and other necessary amendments made. This second face being anointed with oil, a second mould of calcined alabaster is made, consisting of two parts joined lengthwise along the ridge of the nose; and herein may be cast, with the same matter, a face extremely like the original.

If finely powdered alabaster, or plaster of Paris, be put into a bason over a fire, it will, when hot, assume the appearance of a fluid, by rolling in waves, yielding to the touch, steaming, &c., all which properties it again loses on the departure of the heat; and being thrown upon paper, will not at all wet it, but immediately discover itself to be as motionless as before it was set over the fire; whereby it appears, that a heap of such little bodies as are neither spherical, nor otherwise regularly shaped, nor small enough to be below the discernment of the eye, may, without fusion, be made fluid, barely by a sufficiently strong and various agitation of the particles which compose it; and, moreover, lose its fluidity immediately upon the cessation thereof.

Two or three spoonfuls of burnt alabaster mixed up thin with water, in a short time coagulate, at the bottom of a vessel full of water, into a hard lump, notwithstanding the water that surrounded it. Artificers observe, that the coagulating property of burnt alabaster will be very much impaired, or lost, if the powder be kept too long, especially if in the open air, before it is made use of; and when it hath been once tempered with water, and suffered to grow hard, they cannot, by any powdering of it again, make it serviceable for their purpose as before.

This matter, when wrought into vessels, &c., is still of so loose and spongy a texture, that the air has easy passage through it. Mr. Boyle gives an account, among his experiments with the air-pump, of his preparing a tube of this plaster, closed at one end and open at the other, and, on applying the open end to the cement, as is usually done with the receivers, it was found utterly impossible to exhaust all the air out of it; for fresh air, from without, pressed in as fast as the other, or internal air, was exhausted, though the sides of the tube were of considerable thickness. A tube of iron was then put on the machine; so that being filled with water, the tube of plaster of Paris was covered with it; and, on using the pump, it was immediately seen, that the water passed through into it as easily as the air had done, when that was the ambient fluid. After this, trying it with Venice turpentine instead of water, the thing succeeded very well; and the tube might be perfectly exhausted, and would remain in that state several hours. After this, on pouring some hot oil upon the turpentine, the case was much altered; for, the turpentine melting, it became a thinner fluid, and, in this state, capable of passing like water into the pores of the plaster. On taking away the tube after this, it was remarked that the turpentine, which had pervaded and filled its pores, rendered it transparent, in the manner that water

gives transparency to that singular stone called *oculus mundi*. In this manner the weight of air, under proper management, will be capable of making several sorts of glues penetrate plaster of Paris; and not only this, but baked earth, wood, and all other bodies porous enough to admit water on this occasion.

Plaster of Paris, diluted with water into the consistence of a soft or thin paste, quickly sets or grows firm, and, at the instant of its setting, has its bulk increased; for Mr. Boyle has found, that a glass vessel, filled with the fluid mixture, and closely stopped, bursts while the mixture sets, and sometimes a quantity of water issues through the cracks.

This expansion of the plaster, in passing from a soft to a firm state, is one of its valuable properties, rendering it an excellent matter for filling cavities in sundry works, where other earthy mixtures would shrink and leave vacuities, or entirely separate from the adjoining parts.

It is probable, also, that this expansion of the plaster might be made to contribute to the elegance of the impressions it receives from medals, &c., by properly confining the soft matter, that its expansion may force it into the minutest traces of the figure; the expansion of the matter doing the same office as the pressure by which the wax is forced into the cavities of a seal.

Plaster of Paris promotes the fusion of forged iron.

This substance is commonly used for taking casts and impressions from figures, busts, medals, &c., as it is adapted to the double use of making both casts and moulds for forming them.

There is also a plaster of a coarser sort than the plaster of Paris, which is sometimes used in this country for floors in gentlemen's houses, and for corn-granaries: it is made of a blueish stone, taken out of quarries, which are generally at the side of a hill, much like the stone of which Dutch terras is made; the stone is burnt like lime, becomes white by burning, and, when mixed with water, does not ferment like lime: when cold, it is beat into a fine powder; and, when used, the quantity of about a bushel is put into a tub, and water applied to it till it becomes liquid: in this state it is well stirred with a stick, and used immediately; for, in less than a quarter of an hour, it becomes hard and good for nothing, as it will not bear being mixed a second time, like lime.

Plaster Floors, such floors as are constituted of plaster, prepared from such lime as possesses a strong binding property. They are highly useful in cottages and farm-houses, as affording much security against fire. In constructing them, the joists are laid in the usual manner, and on them is nailed a sort of strong reed, found in Huntingdonshire, upon which the plaster is applied; but in order to save it, there is frequently a thin coat of common lime laid on first, to fill up the crevices and inequalities. On this the plaster is then spread out, to the thickness of about two inches, being laid on with as much expedition as possible. The plaster is sold at the kilns in the midland districts, at 6*d.* the bushel; and the expense of laying it on, if burnt and prepared, is 5*d.* the square yard; but if to be burnt and prepared by the workmen, about as much more. These floors are said to be excellent and cheap. Where reeds cannot be procured, laths may be made use of, but they come much higher. Floors of this sort are much in use in Nottinghamshire, as well as in Rutlandshire, where the upper floors of the farm-houses are made of it.

These kinds of floors should be more attended to in constructing small houses, both of the cottage and other kinds, as being cheap, readily laid, and at the same time secure.

PLASTERER, a workman to whom the decorative part of architecture owes a considerable portion of its effect, and whose art is required in every department of building. In ordinary edifices, he lays the ceilings, and covers the walls with a smooth coat, to render them sightly, and prevent the obtrusion of air through any crevices left by the bricklayer and carpenter, or occasioned by settling. In buildings of greater importance, in addition to this service, he also furnishes mouldings, ornamental as well as plain, and covers the exterior walls with stucco, imitative of stone.

The tools of a plasterer consist of *a spade*, or shovel, of the usual description; *a rake*, with two or three prongs, bent downwards from the line of the handle, for mixing the hair and mortar together; *trowels* of two kinds, and various sizes; *stopping* and *picking-out tools*; rules called *straight-edges*; and wood *models*.

Plasterer's *trowels* are more neatly made than the tools of the same name used by other artificers; they are of two sorts, viz., the *laying and smoothing tool*, which consists of a flat piece of hardened iron, about ten inches in length, and two inches and a half wide, very thin, and ground to a semicircular shape at one end, but left square at the other: on the back of the plate, near the square end, is riveted a small iron rod, with two legs, one of which is fixed to the plate; and, to the other, a round wooden handle is adapted; with this tool, all the first coats of plastering are laid on, as are also the last, or the *setting*, as it is technically denominated. The other kind of trowels, which are made of three or four sizes, are for *gauging* the fine stuff and plaster used in forming cornices, mouldings, &c. The longest size of these is about seven inches in length on the plate, which is of polished steel, and two inches and three-quarters broad at the heel, diverging gradually to a point; to the heel, or broad end, a handle is adapted, commonly of mahagony, with a deep brass ferule. The smaller trowels are fitted up in a similar manner, only they gradually vary in size downwards to the length of two or three inches.

The *stopping and picking-out tools* are of polished steel, of various sizes, though most generally about seven or eight inches in length, and half an inch in breadth, flattened at both ends, and ground away to somewhat of a round. These tools are used in modelling and finishing mitres and returns to cornices, as likewise in filling up and perfecting the ornaments at their joinings.

The *straight-edges* are used for keeping the work in an even or perpendicular line; and the *models* or *moulds* are for running plain mouldings, cornices, &c. Of these last, the plasterer requires a great number, as very little of his *finishing* can be completed without them. With a good mould, an adept in his profession may execute most exquisite mouldings, possessing a sharpness and breadth unequalled by any other method now practised.

Good workmen keep their tools very clean; after being used, they are wiped free from the plaster that cleaves to them, before they are put away, and they are daily polished by the hawk-boys.

Plasterers have technical divisions of their work, by which its quality is designated, and from which its value is ascertained; as, *lathing; laying; pricking-up; lathing, laying, and set: lathing, floating, and set; screed; set or putty; rendering and set*, or *rendering, floated, and set; trowelled stucco*, &c., each of which will be found fully described in the next article. *See* Plastering.

Plasterers' work is measured and valued by persons known in the trade as *measurers*, though popularly donominated *surveyors*. All common plastering is measured by the square yard of nine feet; this includes the partitions, walls, and

ceilings of rooms, inside and exterior stuccoing, &c. Cornices are measured by the foot superficial, their numbers being girt to obtain their width; while their length is taken at that of the cornice. Running measures consist of beads, quirks, arrises, and small mouldings. Ornamental cornices are frequently valued by the foot run.

As the labour on plasterer's work is frequently a greater consideration than the materials used, it is necessary for the master to be attentive to the noting down the time occupied by his men in executing their several pieces of plastering; otherwise he will be unable to put an adequate value on his work.

PLASTERING, the art of covering the walls and ceilings of a house, or other edifice, with a composition, of which the ground-work is lime and hair-mortar, finished with a coating of finer materials. It is of various kinds; as white lime and hair mortar on bare walls; the same on laths, as in partitioning and plain ceiling; renewing the insides of walls, or double-partition walls; rough-casting on heart-laths; plastering on brick-work, with finishing-mortar, in imitation of stone-work, and the like upon heart-laths; modelling and casting ornamental and plain mouldings; and making and polishing the scagliola for columns of wood or brick and their antæ.

In all the operations of plastering, lime forms an extensive article, as it pervades the whole; and for its nature, properties, and preparation, the reader is referred to the word Lime; suffice it here to remark, that most of the lime used in London is prepared from chalk, and is brought thither from Purfleet, in Kent; but for stuccoing, and other work requiring strength and permanency, that which is made at Dorking, in Surrey, has a decided pre-eminence.

Next to lime, the plasterer depends much on what is called *plaster of Paris* (see that article); for this alone enables him to give the required form and finish to all the superior parts of his business. With this he makes his ornaments and cornices; and he also mixes it with the lime for filling up the concluding coat to the walls and ceilings of rooms. The name of this composition is derived from the circumstance of its abounding in the hills of Montmartre, in the environs of the French capital; but what is chiefly used in London is prepared from a sulphate of lime dug in Derbyshire.

Cements used by plasterers for inside work are of two or three kinds; the first is called *lime and hair*, or *coarse stuff*, and is prepared as common mortar, only with the addition of hair from the tan-yards being mixed with it. The mortar is first mixed with the requisite quantity of sand, and then the hair is worked in by the labourer with the rake.

Next to this is *fine stuff*, consisting of pure lime slaked with a small quantity of water, and then, without any extraneous addition, supersaturated with water, and put into a tub in a half-fluid state, where it remains till the water is evaporated. In particular cases, a small portion of hair is sometimes worked into this fine stuff, before it is laid on.

For inside walls, this fine stuff is mixed with very fine washed sand, in the proportion of one part sand to three parts of *fine stuff*, and then it obtains the name of *troweled*, or *bastard stucco*, with which all walls intended to be painted are finished. *Gauge-stuff* consists of three-fifths of fine-stuff and one-fifth of plaster of Paris, mixed together with water, in small quantities at a time, to render it more ready to set, or fix itself. This cement is mostly used in forming cornices and mouldings run with a wooden model. When great expedition is requisite, plasterers gauge all their mortars with plaster of Paris, which enables them to proceed with their work, because it sets as soon as laid on.

Next to the materials, the technical divisions of the plasterers' work claim attention, and are as follow —

1. *Lathing:* this operation consists in nailing laths on the ceiling or partition. If the laths be of oak, they will require wrought-iron nails; but if of deal, cast-iron nails may be used. Those mostly used in London are of fir, imported from the Baltic and America, in pieces called *staves*. Laths are made in three-foot and four-foot lengths; and, with respect to their thickness and strength, are either single, lath-and-half, or double. The single are the thinnest and cheapest; those called *lath-and-half* are supposed to be one-third thicker than the single; and the double laths are twice their thickness. In lathing ceilings, the plasterer should use both the lengths alluded to; and, in nailing them up, he should so dispose them that the joints may be as much broken as possible, that they may have the stronger key, or tie, and thereby strengthen the plastering with which they are to be covered. The thinnest laths are used in partitions, and the strongest for ceilings. *See* Lath.

Having nailed the laths in their appropriate order, the next business is to cover them with the plaster, in doing which, the most simple and common operation is that of,

2. *Laying:* this consists in spreading a single coat of lime and hair all over a ceiling, or partition; carefully observing to keep it even and smooth in every direction. This is the cheapest kind of plastering.

3. *Pricking-up* is performed in the same manner as the foregoing, but it is only a preliminary to a more perfect kind of work. After the plaster is laid on, it is crossed all over with the end of a lath, to give it a key, or tie, for the coat that is to be laid upon it.

4. *Lathing, laying, and set*, is when the work, after being lathed, is covered with one coat of lime and hair, and, when that is sufficiently dry, a thin and smooth coat is spread over it, consisting of lime only, or, as the workmen call it, *putty* or *set*. This coat is spread with the smoothing-trowel, which the workman uses with his right hand, while in his left hand he is furnished with a large flat brush of hog's bristles. As he lays on the putty, or set, with the trowel, he draws the brush, dipped in water, backwards and forwards over it, and thus produces a surface tolerably even for cheap work.

5. *Lathing, floating, and set*, differs from the foregoing, in having the first coat pricked up to receive the set, which is here called the *floating*. In performing this last operation, the plasterer is provided with a substantial straight-edge, frequently from ten to twelve feet in length, which must be handled by two workmen. All the parts to be floated are then tried by a plumb-line, to ascertain whether they are perfectly flat and level; and wherever any deficiency appears, the hollow is filled up with a trowel-full, or more, of lime and hair only; this is termed *filling-out;* and when these preliminaries are settled, the *screeds* are begun to be formed.

6. A *screed* signifies a style of lime and hair, about seven or eight inches in width, gauged quite true by drawing the straight-edge over it till it is so. These screeds are made at the distance of about three or four feet from each other, in a vertical direction all round the partitions and walls of a room. When they are all formed, the intervals are filled up with lime and hair, called by the workman *stuff*, till they are flush with the face of the screeds. The straight-edge is then worked horizontally over the screeds, by which all the superfluous stuff, projecting beyond them in the intervals, is removed, and a plain surface is produced. This operation is termed *floating*, and may be applied to ceilings as well as partitions or upright walls, by first forming the screeds, in the direction of the breadth of the apartment, and filling up the intervals as above described. As great care is requisite

in this kind of work, to render the plaster sound and even, none but skilful workmen should be employed upon it.

7. The *set* to floated work is performed in a mode similar to that already prescribed for *laying ;* only, as it is employed for best rooms, it is done with more care. There is also added to it about one-sixth of plaster of Paris, to make it set more expeditiously, and give it a closer and more compact appearance, as well as to render it more firm, and better calculated to receive the white-wash, or colour, when dry. For floated stucco work, the pricking-up coat cannot be too dry ; but, if the floating that is to receive the setting coat be too dry before the set is laid on, there will be danger of its peeling off, or of its assuming the appearance of little cracks, or shells, which would disfigure the work. Particular attention is therefore to be paid to have the under-coats in a due state of dryness when the exterior surface is laid on. And here it may also be remarked, that cracks and other unpleasant appearances in ceilings are more frequently the effect of weakness in the laths, covered with too much plaster ; or, on the contrary, of too little plaster upon strong laths, than of any sagging, or other inadequacy in the timbers of the building. If the laths be properly attended to, and the plastering laid on by a judicious careful workman, no cracks are likely to appear.

8. *Rendering, and set*, or *rendering floated, and set*, combines both the foregoing processes, only it requires no lathing. *Rendering* is to be understood of a wall, whether of brick or stone, being covered with a coat of lime and hair ; and by *set* is denoted a superficial coat, upon the rendering of fine stuff or putty. These operations are similar to those described for setting of ceilings and partitions; and the *floated and set* is laid on the rendering in the same manner as on partitions, &c., as above explained for the best kind of work.

9. *Troweled stucco*, which is a very neat kind of work, used in dining-rooms, halls, &c., when the walls are proposed to be painted, must be worked upon a floated ground, and the floating should be as dry as possible before the stucco is applied. In this process, the plasterer is provided with a wooden tool, called *a float*, consisting of a piece of half-inch deal, about nine inches long and three wide, planed smooth, with its lower edges a little rounded off, and having a handle on the upper surface. The stucco is prepared as described above, and afterwards well beaten and tempered, with clean water, for use. The ground intended to be stuccoed is first prepared with the large trowel, and made as smooth and level as possible ; and when the stucco has been spread upon it, to the extent of four or five feet square, the workman, with the float in his right hand, and a brush in his left, begins to rub it smooth with the former, having first sprinkled it with water from the latter : this he does in small portions at a time, and proceeds, alternately sprinkling and rubbing the face of the stucco, till the whole is reduced to a fine even surface. He then prepares another square of the ground, and proceeds as before, till the whole is completed. The water has the effect of hardening the face of the stucco, and, when the floating is well performed, it will feel as smooth as glass.

Rough-casting, or *rough-walling*, is an exterior finishing, much cheaper than stucco, and therefore more frequently employed on cottages, farm-houses, &c., than on buildings of a higher class. The wall intended to be rough-cast is first pricked-up with a coat of lime and hair ; and when this is tolerably dry, a second coat is laid on, of the same materials as the first, but as smooth as it can possibly be spread. As fast as the workman finishes this surface, he is followed by another, with a pail-full of rough-cast, with which he bespatters the new plastering, and the whole dries together. The rough-cast is composed of fine gravel, clean washed from all earthy particles, and mixed with pure lime and water, till the whole is of a semi-fluid consistency. This is thrown from the pail, upon the wall, with a wooden float, about five or six inches long, and as many wide, made of half-inch deal, and fitted with a round deal handle. While, with this tool, the plasterer throws on the rough-cast with his right hand, he holds in his left a common whitewasher's brush, dipped in the rough-cast also, with which he brushes and colours the mortar, and the rough-cast he has already spread, to give them, when finished, a regular uniform colour and appearance.

Cornices.—These are either plain or ornamented ; and sometimes they embrace a portion of both classes. The first thing here to be attended to, is to examine the drawings, and measure the projections of the members : if they project more than seven or eight inches, bracketing must be resorted to. This consists in fixing up pieces of wood, at the distance of about eleven or twelve inches from each other, all round the place proposed for the cornice, nailing laths to them, and covering the whole with a coat of plaster, allowing in the brackets for the stuff necessary to form the cornice : in general, about one inch and a quarter is sufficient. A beech mould is next to be made of the profile of the intended cornice, by the carpenter, of about a quarter of an inch in thickness, with the quirks, or small sinkings, of brass. All the sharp edges are to be carefully removed by the plasterer, who must also open, with his knife, all the points that he finds incompetent to receive the plaster freely. These preliminaries being adjusted, two workmen, provided with a tub of putty, and a quantity of plaster of Paris, proceed to run the cornice. Before they begin, however, to use the mould, they gauge a screed upon the wall and ceiling, of putty and plaster, covering so much of each as will correspond with the top and bottom of the intended cornice. On this screed, one or two slight deal straight-edges are nailed, adapted to as many notches, or chases, made in the mould, for it to work upon. The putty is then to be mixed with about one-third of plaster of Paris, and brought to a semi-fluid state by the addition of clean water. One of the workmen, with two or three trowelfuls of this composition upon his *hawk*, which he holds in his left hand, begins to plaster over the surface intended for the cornice, with his trowel, while his partner applies the mould, to ascertain the parts where more or less may be wanted. When a sufficient quantity of plaster has been laid on, the workman with the mould, holding it steadily and firmly against both the ceiling and the wall, moves it backwards and forwards, which removes the superfluous stuff, and leaves an exact impression of the mould upon the plaster. This is not indeed effected at once, but while he works the mould to and fro, the other workman takes notice of any deficiencies, and fills them up, by adding fresh supplies of plaster. In this manner, a cornice of from ten to twelve feet in length, may be formed in a very short time; indeed, expedition is essentially requisite, as the plaster of Paris occasions a very great tendency in the putty to set; and to prevent this taking place too rapidly, it is necessary to sprinkle the composition frequently with water from a brush; as they generally endeavour to finish all the lengths, or pieces, between any two breaks, or projections, at one time, to secure the truth and correctness of the cornice. In cornices of very large proportions, and in cases where the orders of architecture are to be applied, three or four moulds are requisite, which are applied in the same manner, till all the parts are formed. Internal and external mitres, and small returns, or breaks, are afterwards modelled and filled up by hand; ar

operation upon which a dexterous plasterer much piques himself.

When cornices are to be charged with ornaments, the plasterer leaves certain indentions, or sinkings, in the mould, in which the casts are laid. These ornaments were formerly made by hand, by artists called *ornament-plasterers;* but now they are cast in plaster of Paris, which has almost superseded that branch of art; at least, the few professors of it who remain, are limited in their labours to the modelling and forming of moulds to cast from. Ornaments, to be cast in plaster of Paris, are previously modelled in clay from the design. When the clay model is finished, and has acquired some degree of firmness from the action of the atmosphere, a wooden frame is adapted to it, and after it has been retouched, and finished, the frame is filled up with melted wax, which, when cool, on the mould being turned upside-down, drops off, and presents an exact cameo, or counterpart, of the model, in which the most enriched and curiously-wrought mouldings may be cast by the common plasterer. These wax models are contrived to cast about a foot in length of the ornament at once; such lengths being most easily got out from the cameo. The casts are made of the finest and purest plaster of Paris, saturated with water; the wax mould being oiled previously to its being poured in. When first taken from the mould, the casts, or intaglios, are not very firm; but after they have been suffered to dry a little, either in the open air or in an oven, they become hard, and are scraped and cleaned up for the workmen.

Friezes and basso-relievos are executed in a similar manner, only the wax mould is so contrived that the cast may have a back ground of plaster, at least half an inch thick: this is cast to the ornament, or figure, so that it strengthens and secures their proportions, at the same time that it promotes their general effect.

Nor is the process different for capitals to columns, except that they require a number of moulds to complete them. To make a good mould, however, requires the utmost skill of the modeller. The Corinthian capital requires a shaft, or bell, to be first made, on which are afterwards to be fixed the foliage and volutes; all which, as well as the other details, require distinct cameos.

In forming cornices that are to be charged with ornaments, the plasterer takes care to have proper projections in the running mould, so as to leave a groove or indention in the cornice, into which the cast ornament is laid, and secured in its place, by spreading a small quantity of liquid plaster of Paris on its back. Friezes, likewise, are prepared for in the cornice in a similar manner, by leaving a projection in the running mould, at the part where they are intended to be inserted, and they are fixed in their places by liquid plaster. Detached ornaments, designed for a ceiling, or other part, where no running mould has been employed, are cast in pieces, corresponding with the design, and fixed upon the ceiling, &c. with white-lead, or the composition known under the name of *iron cement.*

Good plastering is known by its exquisite appearance, both as to regularity and correctness, and its solid effect having no cracks, nor indications of them, visible.

The making and working of stucco has, for a considerable time past, occupied the attention of chemists, physicians, architects, and plasterers; but the only beneficial result has been a more extensive knowledge of the materials used in it: indeed, our climate, from its great moisture, prevents its being brought to superlative perfection, though, among the various compositions that have been proposed and tried, some are comparatively excellent. The common stucco now in use for external work, is known, among plasterers, by the name of *Bailey's compo;* it consists of Thames sand cleanly washed, and ground Dorking lime, mixed dry, in the proportion of three of the latter to one of the former, which when well incorporated together, should be secured from the air in good tight casks, till the moment it is wanted for use. Walls intended to be covered with this composition, must be first prepared, by raking the mortar from the joints, and picking the bricks, or stones, till the whole wall is properly indented. The part must then be clean brushed of all dust and other extraneous matter, and well soaked with clean water. The stucco is then to be supersaturated with water, till it bears the appearance and consistence of ordinary whitewash: in which state it is to be rubbed over the wall with a flat brush of hogs' bristles, and then left to become tolerably dry and hard, which is ascertained by its becoming more white and transparent than when at first laid on. This process is called *roughing in.* Screeds are next to be formed upon the wall, with fresh stucco from the cask, tempered with water to a proper consistency, and spread on the upper part of the wall about eight or nine inches wide, and against the two ends, beginning at the top, and proceeding downwards to the bottom. In this operation, two workmen are required; one to supply the stucco, the other to use and try the plumb-rule and straight-edge. When these are truly formed, other screeds must be made, vertically, about four or five feet apart, unless apertures in the wall should prevent it, in which case they must be formed as near together as possible. When the screeding is all done, more *compo* must be prepared, and in larger quantities than was done for the former process; and, when ready, both the workmen begin to spread it with their trowels over the wall in the space left between each pair of screeds that are nearest together. When this is done the straight-edge is to be applied across both, and dragged from the top to the bottom, so as to remove whatever superfluous stucco may project above the screeds. Should any hollow places appear, fresh stucco must be applied, and the straight-edge again drawn over the spot, till the *compo* is brought even to the face of the screeds, and the whole is level with the edge of the rule. The workmen then fill up another interval; and thus they proceed, till the whole of the wall is covered. The wall is then to be finished, by floating, or hardening the surface, by rubbing it with the common wood float, and sprinkling it with water, an operation that is performed, as above directed, for troweled stucco; always remembering to begin the floating on the part first filled up.

This kind of compo, or stucco, is frequently used by plasterers for cornices and mouldings, in the same manner that has already been described in common plastering. But here, the workman finds requisite to add a small portion of plaster of Paris, to make it fix better while running or working the mould. Such addition, however, is not calculated to give strength to the stucco; and is only made through the necessity of having a quick set.

Some years ago, the patent stucco of Dr. B. Higgins, was in great repute, and employed by the founders of the Adelphi, in the Strand, with considerable success. It consisted of 14lb. or 15lb. of good stone lime, 14lb. of bone-ashes, finely powdered, and 98lb. of clean sand, coarse or fine, according to the intended nature of the building: these were mixed up into mortar as quickly as possible with lime-water, and used as soon as made.

The various suggestions and modes of forming the same materials into stucco, amount to about forty in number, only varying the proportions; but few of them have been found to remain tolerably entire in this climate for thirty years together. In 1796, Mr. Parker obtained a patent for

a cement that is impervious to water, and may be successfully employed in ice-houses, cisterns, tanks, &c. (*See* CEMENT, and MORTAR.) In his specification, Mr. Parker observes, "nodules of clay, or argillaceous stone, generally contain water in their centre, surrounded by calcareous crystals, and having veins of calcareous matter. They are formed in clay, and are of a brown colour, like the clay." These nodules, he directs, should be burned, after being broke into small pieces, in a kiln, with a heat nearly sufficient to vitrify them; after which they are to be reduced to powder. Two measures of water added to five of this powder, produces *tarras;* lime and other matters may be added or withheld at pleasure: and the proportion of water may be varied. The term of the patent being now expired, there are many other manufactures of this cement, which are found to be of equal goodness as to quality, and some of them of rather a better colour than the original; a recommendation, or rather improvement, of considerable importance, since the fresco-painting, or whitewash, laid upon Mr. Parker's composition, when applied to the fronts of houses, is soon taken off by the rains, and leaves the walls of a dingy and unpleasant appearance.

An allusion has been made above, to the fresco-painting, or staining, laid upon walls plastered with this cement; this is done to give them an appearance of stone-buildings, and is performed by diluting sulphuric acid (oil of vitriol) with water, and adding the fluid ochres, &c., to give the required tint. When the stucco is washed over with this kind of paint, the affinity existing in the iron of the cement ceases, the acid and colour suspended in and upon the stucco is fixed, and the surface assumes, when dexterously managed, the appearance of an ashlar bond of masonry.

Columns, &c. done in Scagliola, is a distinct branch of plastering, discovered or invented in Italy, where it has been much used, and thence introduced into France, where, having fascinated all the cognoscenti, it obtained the title of *scagliola*. The late Henry Holland, who first brought it to England, engaged the artists from Paris to execute it; some of whom, finding a demand here for their labour, remained in the country, and instructed our own workmen in the art. Columns and pilasters are executed in this branch of plastering, in the following manner. A wooden cradle, composed of thin strips of deal, or other wood, is made to represent the column designed, but about $2\frac{1}{2}$ inches less in diameter than the shaft is intended to be when finished. This cradle is lathed round, as for common plastering, and then covered with a pricking-up coat of lime and hair: when this is quite dry, the artists in scagliola commence their operations, and, by an imitation of the most rare and precious marbles, produce a most astonishing and delusive effect; for, nothing short of actual fracture can discover the counterfeit: and any stone, partaking of the quality of marble, may be exactly imitated by it; the imitation taking as high a polish, and feeling to the touch as cold and solid, as the most compact and solid marble. The workmen select the purest gypsum they can obtain, which, after breaking it into small pieces, they calcine. As soon as the largest fragments lose their brilliancy, the fire is withdrawn; the calcined powder is passed through a very fine sieve, and mixed up as it is to be used with a solution of Flanders glue, isinglass, &c. In this solution the colours required in the marble to be imitated are also diffused: but when the work is to be of various colours, each colour is separately prepared, and they are afterwards mingled and combined, nearly in the same manner that a painter mixes the primitive colours on his palette, to compose his different tints. When the powdered gypsum is prepared and mingled for the work, it is laid on the shaft of the column, &c. over the pricked-up coat of lime and hair, and then it is floated with moulds of wood, made to the requisite size, the artist using the colours necessary for the imitation during the floating, by which means they become mingled and incorporated with the surface. To give the work the requisite polish, or glossy lustre, so much admired in works of marble, the workman rubs it with a pumice-stone with one hand, while with the other he cleans it with a wet sponge. He then polishes it with tripoli and charcoal and fine soft linen; and after going over it with a piece of felt dipped in a mixture of oil and tripoli, he finishes the process by the application of pure oil.

This imitation is the most complete that could be conceived; and, when the bases and capitals are made of real marble, as is the common practice, the deception is beyond discovery. When not exposed to the weather, it is also little inferior to real marble in point of durability, retains its lustre full as long, and is not one-eighth of the expense of the cheapest imported.

There is another species of plastering, though done by a distinct set of persons, known to the public by the name of *composition ornament*, used not only for the decorative parts of architecture, but also for the frames of pictures, looking-glasses, &c. This composition, which is very strong when quite dry, and of a brownish colour, consists of the proportion of two pounds of powdered whiting, one pound of glue in solution, and half a pound of linseed-oil, mixed together in a copper, heated, and stirred with a spatula till the whole is incorporated. After being suffered to stand to settle and cool, it is laid upon a stone, covered with powdered whiting, and beaten till it assumes a tough and firm consistence; after which it is put by for use, and covered with wet cloths to keep it fresh. The ornaments to be cast in this composition are modelled in clay, as for common plastering, and afterwards a cameo, or mould, is carved in a block of box-wood. This carving requires to be done with the utmost neatness and truth, otherwise the symmetry of the ornament to be cast from it will be spoiled. When the composition is to be used, it is cut with a knife into pieces adapted to the size of the mould, and forced with the hand closely into every part. It is then placed in a press worked by an iron screw, by which it is farther compressed into every crevice: after being removed from the press, the mould is turned upside-down, with a smart tap on a board, which dislodges the composition, and the mould leaves it with its face upwards. One foot in length is as much as is usually cast at one time, and when the ornament first drops from the mould, all the superfluous composition is pared away with a knife, and thrown into the copper towards a fresh supply for the next cast. The ornaments, when formed, are glued upon wooden, or other grounds, or they are affixed by means of white-lead, &c., after which they are painted or gilt, according to the purpose for which they are intended. This composition is at least 80 per cent. cheaper than carving, and in most cases is equally well calculated to answer all the purposes of that art.

It were much to be wished, that the art of plastering could be again brought to its ancient perfection. In our best buildings, the plastered walls and ceilings crack and fly, and, in a little time, grow damp, or moulder to decay.

The Romans had an art of rendering their work of this kind much more firm and durable; and there is no reason to despair of reviving this art by proper trials.

The ancient plastering of these people, preserved to this time, where it has not met with violent blows, or injuries from accidents, is still found as firm and solid, as free from cracks or crevices, and as smooth and polished on the surface, as if made of marble. The bottoms and sides of the

Roman aqueducts were lined with this plastering, and endured many ages without hurt, unless by accidents: witness that whereof some yards are still to be found on the top of the Pont de Gard, near Nismes, for the support of which that celebrated bridge was built to carry water to the said town. The roofs of houses, and the floors of rooms, at Venice, are covered with a sort of plaster, of later date, and yet strong enough to endure the sun and weather for several ages, without cracking or spoiling, and without much injury from being trod upon.

The secret of preparing this Venetian plaster is not among us; but it would be worth while to try whether such a substance might not be made by boiling the powder of gypsum dry over the fire (for it will boil in the manner of water); and when this boiling or recalcining is over, mixing with it resin, or pitch, or both together, with common sulphur, and the powder of sea-shells. If these were all mixed together, the water added to it hot, and the matter all kept upon the fire till the instant of its being used, so that it might be laid on hot, it is possible this secret might be hit upon.

Wax and oil of turpentine may be also tried as additions; these being the common ingredients in such cements that we have accounts of as the firmest. Strong ale-wort is, by some, directed to be used instead of water, to make mortar of limestone of a more than ordinary strength. It is possible that the addition of this tenacious liquor to the powdered ingredients of this proposed plaster, might greatly add to their solidity and firmness. *See* CEMENT, MORTAR, and STUCCO.

PLATBAND, any flat square moulding, whose height much exceeds its projecture. Such are the faces, or fasciæ, of an architrave, and the platbands of the modillions of a cornice.

The platband is signified, in Vitruvius and others, by the words *fascia*, *tænia*, and *corsa*.

PLATBAND OF A DOOR OR WINDOW, is used for the lintel, where that is made square, or not much arched. These platbands are usually crossed with bars of iron, when they have a great bearing; but it is much better to ease them by arches of discharge built over them.

PLATBANDS OF FLUTINGS, are the lists, or fillets, between the flutings of columns.

PLATE, a term applied generally to those horizontal timbers bedded in brick, or other walls, for the purpose of sustaining other timbers, &c.: thus we have *wall-plate*, *gutter-plate*, &c.

PLATE-GLASS, *see* GLASS.

PLATES, *Ground*, *see* GROUND-SILL.

PLATFOND, the same as soffit. *See* SOFFIT.

PLATFORM, a row of beams, which support the timber-work of a roof, and lie at the top of the wall where the entablature ought to be raised.

PLATFORM is also used for a kind of terrace, or broad, smooth, open walk, at the top of a building, whence a fair prospect of the adjacent country may be taken. Hence an edifice is said to be covered with a platform, when it is flat at top, and has no ridge. Most of the Oriental buildings are thus covered, as were all those of the ancients. Cæsar was the first among the Romans who procured leave to build his house with a ridge or pinnacle.

PLINTH (from πλινθος, *a brick*), a flat square member, in form of a brick: sometimes, also, called *the slipper*.

It is used as the foot, or foundation of columns; being that flat square table, under the mouldings of the base and pedestal, at the bottom of the whole order; seeming, if we follow the notion of Vitruvius, to have been originally intended to keep the bottom of the primitive wooden pillars from rotting.

The plinth is also called the *orle* or *orlo*. And Vitruvius calls the Tuscan abacus, *plinth*, from its resembling a square brick.

PLINTH OF A STATUE, &c., a base or stand, flat, round, or square, serving to support a statue, &c.

PLINTH OF A WALL, a term for two or three rows of bricks advancing out from the wall; or, in general, for any flat high moulding, serving in a front wall to mark the floors, or to sustain the eaves of a wall, and the larmier of a chimney.

PLOTTING, among surveyors, the art of describing, or laying down on paper, &c., the several angles and lines of a tract of ground surveyed by a theodolite, or like instrument, and a chain.

In surveying with the plain-table, the plotting is needless; the several angles and distances being laid down on the spot, as fast as they are taken. But in working with the theodolite, semicircle, or circumferentor, the angles are taken in degrees, and the distances in chains and links; so that there remains a subsequent operation, to reduce those numbers into lines, and thence to form a draught, plan, or map. This operation is called *plotting*.

Plotting is performed by means of two instruments, the protractor and plotting-scale. By the first, the several angles observed in the field with a theodolite, or the like, and entered down in degrees in the field-book, are protracted on paper in their just quantity. By the latter, the several distances measured with the chain, and entered down, in like manner, in the field-book, are laid down in their just proportion.

PLOTTING-SCALE, a mathematical instrument, used in plotting grounds, usually of box-wood, sometimes of brass, ivory, or silver, either a foot or half a foot long, and about an inch and a half broad.

On one side of the instrument are seven several scales or lines, divided into equal parts. The first division of the first scale is subdivided into ten equal parts, to which is prefixed the number 10, signifying that ten of those subdivisions make an inch; or that the division of that scale are decimals of inches.

The first division of the second scale is likewise subdivided into 10, to which is prefixed the number 16, denoting that sixteen of those subdivisions make an inch. The first division of the third scale is subdivided, in like manner, into 10, to which is prefixed the number 20. To that of the fourth scale is prefixed the number 24; to that of the fifth, 30; that of the sixth, 40; and that of the seventh, 48; denoting the number of subdivisions equal to an inch, in each respectively. The two last scales are broken off before the end, to give room for two lines of chords, marked by the letters c c.

On the other side of the instrument is a diagonal scale, the first of whose divisions, which is an inch long, if the scale be a foot, and half an inch, if half a foot, is subdivided diagonally into 100 equal parts; and at the other end of the scale is another diagonal subdivision, of half the length of the former, into the same number of parts, viz., 100.

Next the scales is a line divided into hundredth-parts of a foot, numbered 10, 20, 30, &c., and a line of inches subdivided into tenths, marked 1, 2, 3, &c.

PLUG AND FEATHER, or KEY AND FEATHER, a method of dividing hard stones, described at length in the article EDDYSTONE LIGHTHOUSE.

PLUGS, pieces of timber driven perpendicularly into a wall, with the projecting part sawn away, so as to be flush with the face.

PLUMBER, (from the French *plombier*, derived from the

Latin *plumbum*, lead), an artist who works in lead, and to whom is confided the pump-work, as well as the making and forming of cisterns and reservoirs, large or small, water-closets, &c., for the purposes of domestic economy. The plumber does not use a great variety of working tools, because the ductility of the metal upon which he operates does not require them. They consist of an iron *hammer*, rather heavier than a carpenter's, and with a short thick handle; two or three wooden *mallets*, of different sizes; and a *dressing and flatting tool*. This last is of beech, about 18 inches long and 2½ inches square, planed smooth and flat on the under surface, rounded on the upper, and one of its ends tapered off round, as a handle. With this tool the plumber stretches out and flattens the sheet-lead, or dresses it to the shape required, using first the flat side, and then the round one, as occasion may suit. The plumber has also occasion for a *jack* and a *trying* plane, similar to those of the carpenter (see PLANE), with which he reduces the edges of sheet-lead to a straight line, when the purposes to which it is to be applied require it. He should also be provided with a *chalk-line*, wound upon a roller, for marking out the lead into such breadths as he may want. His cutting-tools consist of a variety of *chisels* and *gouges*, as well as *knives;* the latter of which are used for cutting the sheet-lead into slips and pieces, after it has been marked out by the chalk-line. *Files* of different sizes are requisite for the plumber, in various operations. In soldering, *ladles* of three or four sizes, for melting the solder; and iron instruments, called *grozing-irons*, are used by the plumber. These grozing-irons are of several sizes, and commonly about 12 inches in length, tapering at both ends, the handle-end being turned quite round, to allow of its being firmly held while in use. The other end is a bulb, of a spindle-shape, or sometimes spherical, of a size proportioned to the soldering intended to be executed. They are heated to redness, when wanted for use.

A plumber's *measuring rule* is two feet in length, divided into three equal parts of eight inches each. Two of its legs are of box-wood, and duodecimally divided; the third leg consists of a piece of slow-tempered steel, attached to one of the box-legs, by a pivot, on which it turns, and falls, when not in use, into a groove cut in such leg for its reception. This steel leg will pass into places that the others could not enter, and is also useful for occasionally removing the oxide, or any other extraneous matter, from the surface of his heated metal.

Scales and weights are also necessary to the master plumber, as he cannot charge for anything till it has been weighed. He must also be supplied with *centre-bits* of all sizes, and a *stock*, to work them in, for the purpose of making perforations in lead or wood, through which he may want to insert pipes, &c. He also has occasional recourse to compasses, to strike circular pieces of lead, to line or cover figures of that shape. Plumbers charge their sheet-lead by the hundred-weight.

PLUMBERY, or PLUMBING, (from the Latin *plumbum*, lead), the art of casting and working in lead, and using it in building. As this metal is very easily fusible, it is cast into figures of any kind, with great facility, by running it in proper moulds of clay, plaster, &c., but the chief articles in plumbery are sheets and pipes of lead; which form the basis of the plumber's work.

Lead is obtained from the mines, and, from its being generally combined with sulphur, it has been denominated a *sulphuret*. After the ore has been taken from its bed, it is smelted, first being picked, in order to separate the unctuous and rich, or genuine ore, from the stony matrix and other impurities; the picked ore is then pounded under stampers, actuated by machinery, and afterwards washed to carry off the remainder of the matrix, that could not be separated in picking. It is next put into a reverberatory furnace to be *roasted*, as the workmen call it, during which operation it is repeatedly stirred to facilitate the evaporation of the sulphur. When the surface begins to assume the appearance of a paste, it is covered with charcoal, and well shaken together: the fire is then increased, and the purified lead flows down on all sides into the basin of the furnace, whence it runs off into moulds prepared for its reception. The moulds are capable of receiving 154lb. of lead each; and their contents, when cool, are called *pigs* in the commercial world.

The natural colour of lead is a bluish white; when newly melted, or cut, it is very bright; but is soon tarnished on exposure to the atmosphere; assuming first a dirty gray colour, which afterwards becomes white. It is capable of being hammered into very thin plates, and may be drawn into wire; but its tenacity is very inferior to that of other metals; for a leaden wire the hundred-and-twentieth part of an inch in diameter is only capable of supporting 18.4lb. without breaking. Lead melts at the temperature of 612° of Fahrenheit's thermometer; and, if a stronger heat be applied, it boils and evaporates. If cooled slowly, it crystallizes. The change of its external colour is owing to its gradual combination with oxygen, which converts its exterior surface into an oxide: this outward crust, however, preserves the rest of the metal for a long time, as the air can penetrate it but very slowly. Lead is not acted upon immediately by water, though that element greatly facilitates the action of the air upon it; for it is known, that when lead is exposed to the atmosphere, and kept constantly wet, the process of oxidation takes place much more rapidly than it does under other circumstances: hence the white crust, that is to be observed upon the sides of leaden vessels containing water, just at the place where the surface of the water terminates. For other particulars relative to this metal, *see* LEAD.

Plumbers purchase lead in *pigs*, and reduce it themselves into sheets, or pipes, as they have occasion. Of sheet-lead, they have two kinds, cast and milled; the former is used for covering flat roofs of buildings, laying of terraces, forming gutters, lining reservoirs, &c.; the latter, which is very thin, for covering the hips and ridges of roofs: this last they do not manufacture themselves, but purchase it ready prepared of the lead merchants, as it comes from the ore and roasting furnaces.

In casting sheet lead, a copper is provided, well fixed in masonry at the upper end of the workshop, near the mould, or casting-table, which consists of strong deal boards, well jointed together, and bound with bars of iron at the ends. The sides of this table, of which the shape is a parallelogram, varying in size from 4 to 6 feet in width, and from 16 to 18 feet and upwards in length, are guarded by a frame or edging of wood, 3 inches thick, and 4 or 5 inches higher than the interior surface, called the *shafts*; the table is fixed upon firm legs, strongly framed together, about 6 or 7 inches lower than the top of the copper; at the upper end of the mould, nearest the copper, a box, called *the pan*, is adapted in its length to the breadth of the table, having at its bottom a long horizontal slit, from which the heated metal is to issue, after it has been poured in from the copper. This box moves upon rollers along the surface of the rim of the table, and is put in motion by means of ropes and pulleys fixed to beams above. While the metal is melting, the surface of the mould, or table, is prepared by covering it with a stratum of dry and clean sand, regularly smoothed over with a kind of rake, called *a strike* which consists of a board,

about 5 inches broad, and rather longer than the inside of the mould, so that its ends, which are notched about two inches deep, may ride upon the shafts; this, being passed down the whole length of the table, reduces the sand to a uniform surface. When this is done, the pan is brought to the head of the table, close to the copper, its side having been previously guarded by a coat of moistened sand, to prevent its firing from the heat of the metal, which is now emptied in with ladles from the copper. These pans, or boxes, it must be observed, are made, as to their contents, equal to the quantity of melted lead requiredto cast a whole sheet at one time; and the slit in the bottom is so adjusted as to let out, during its progress along the table, just as much as will completely cover it, of the thickness and weight per foot required. Everything being thus prepared, the slit is opened, and the box is moved along the table, dispersing its contents from the top to the bottom, and leaving in its progress a sheet of lead of the desired thickness. When cool, the sheet is rolled up and removed from the table, and other sheets are cast, till all the metal in the copper is exhausted. The sheets so formed are rolled up, and weighed, it being by weight that the public is charged for sheet lead.

In some places, instead of having a square box, upon wheels, with a slit in the bottom, the pan consists of a kind of trough, being composed of two planks nailed together at right angles in their length, with two triangular pieces fitted in between them at their ends. The length of this pan, as well as that of the box, is equal to the whole breadth of the mould: it stands with its bottom, which is a sharp edge, on a bench at the head of the table, leaning with one side against it: and on the opposite side is a handle to lift it up by, in order to pour out the liquid metal. On the side of the pan next the mould, are two iron hooks to hold it to the table, and prevent it from slipping, while the metal is pouring out of it into the mould. The mould, as well as the pan, is spread over, about two inches thick, with sand sifted and moistened, which is rendered perfectly level by moving over it the strike, and smoothing it down with a plane of polished brass, about a quarter of an inch thick, and nine inches square, turned up on all the four edges, and with a handle fitted to the upper, or concave side. Before they begin to cast, the strike is made ready, by tacking two pieces of old hat on the notches, or by covering them with leather cases, so as to raise the under side of the strike about the eighth of an inch, or more, above the sand, according to the proposed thickness of the sheet: the face, or under surface of the strike is then smeared with tallow, and laid across the breadth of the mould, with its ends resting on the shafts. The melted lead is then put into the pan with ladles, and, when a sufficient quantity has been put in, the scum is swept off with a piece of board to the edge of the pan, and is suffered to settle on the coat of sand, to prevent its falling into the mould when the metal is poured out. It generally happens, that the lead, when first taken from the copper, is too hot for casting; it is therefore suffered to cool in the pan, till it begins to stand with a shell or wall on the sand with which the pan is lined. Two men then take the pan by the handle, or one man takes it by means of a bar and chain fixed to a beam in the ceiling, and, turning it down, the metal runs into the mould: another man stands ready with the strike, and as soon as all the metal is poured in, he sweeps it forward, and draws the residue into a trough at the bottom prepared to receive the refuse. The sheet is then rolled up, as before. In this mode of operation, the table inclines in its length about an inch, or an inch and a half, in the length of 16 or 17 feet, or more, according to the required thickness of the sheets; the thinner the sheet the greater the declivity, and *vice versa;* the lower end of the mould is also left open, to admit of the superfluous metal being thrown off.

When it is intended to cast a cistern, the size of the four sides is measured out; and the dimensions of the front having been taken, long slips of wood, on which the mouldings are carved, are pressed upon the sand, and leave their impression; and figures of birds, beasts, &c. are likewise stamped in the internal area, by means of leaden moulds: whatever of the sand has been disturbed in doing this, is then made smooth, and the process of casting goes on as for plain sheets; only, instead of rolling up the lead when cast, it is bent into four sides, so that the two ends may be joined at the back, where they are soldered together; and afterwards the bottom is soldered up.

The lead that lines the Chinese tea-boxes, is reduced to a degree of thinness, to which European plumbers cannot, it is said, approach. The following account of the process by which these plates are formed, was communicated to a writer in the *Gentleman's Magazine*, by an intelligent mate of an East-Indiaman: The caster sits by a pot, containing the melted metal, and has two large stones, the lower one fixed, and the upper moveable, having their surfaces of contact ground to each other, directly before him. He raises the upper stone by pressing his foot upon its side, and with an iron ladle pours into the opening a proper quantity of the fluid metal. He then lets fall the upper stone, and thus forms the lead into an extremely thin irregular plate, which is afterwards cut into a proper shape.

Cast sheet lead, used for architectural purposes, is technically divided into lead of 5lb. 5½lb. 6lb. 6½lb. 7lb. 7½lb. 8lb. and 8½lb. by which is understood that every superficial foot is to contain those respective weights, according to the price agreed upon.

The milled lead used by plumbers is very thin, seldom containing more than 4lb. to the foot. It is by no means adapted to gutters or terraces, nor indeed to any part of a building that is much exposed either to great wear, or to the effects of the sun's rays: in the former case it soon wears away; in the latter it expands and cracks. It is laminated in sheets of about the same size as those of cast lead, by means of a roller, or flatting-mill.

To cast pipes without soldering, a kind of mill, furnished with arms, or levers, to turn it by, is used. The moulds, which are of brass, consist of two pieces, which open and shut by hooks and hinges; their inward calibre, or diameter, being according to the size of the intended pipe, and usually about two feet and a half in length. In the middle is a core, or round piece of brass, or iron, rather longer than the mould, and of the thickness of the proposed inward diameter of the pipe. This core passes through two copper rundles, one at each end of the mould, which they serve to close; and to this is joined a small copper tube, about two inches long, of the intended thickness of the leaden pipe. These small tubes retain the core in the centre of the cavity of the mould. The core being in the mould, with the rundles at its two ends, and the lead melted in the furnace, the metal is taken up in a ladle and poured into the mould through a small aperture, in the shape of a funnel, at one end. When the mould is full, a hook is passed into the end of the core, which, by turning the mill, is drawn out; the mould is then opened, and the pipe itself is taken away. If it be desired to have the pipe lengthened, one end of it is put in the lower part of the mould, with the extremity of the core passed into it: the mould is then shut, and the upper rundle and tube applied as before; the pipe serving for rundle and tube at the other end. Fresh metal is then poured in, which unites

itself with the former length of pipe; and the operation being repeated, a pipe of any required length may be obtained.

Pipes are made of sheet-lead, by beating it round wooden cylinders of the length and thickness required; and then soldering up the edges.

Both these methods are now superseded, by the use of a machine, worked by steam, which produces a much neater article, of almost any length, and at considerably less expense.

Solder is used by plumbers to secure the joints of lead-work, where other means would be improper, or impossible. It is a rule, that solder should be easier of fusion than the metal intended to be soldered; and that it should be as nearly as possible of the same colour. The plumber, therefore, uses what is technically called *soft solder*, which is a compound of equal parts of tin and lead, fused together, and run into moulds, not much unlike, in shape, to a gridiron: in which state it is sold to the manufacturer by the pound. In the operation of soldering, the surfaces, or edges, intended to be united are scraped very clean, and brought close up to each other, in which state they are secured by an assistant, while the plumber lays a little resin, or borax, upon the joint, to prevent an oxidation of the metal. The heated solder is then brought in a ladle and poured on the joint, after which it is smoothed and finished, by rubbing it about with a red-hot grozing iron; and, when completed, it is made smooth by filing.

For the method of laying embossed figures upon a leaden ground, see the article Lead.

In covering terraces, or flats, with sheet-lead, a bottom, as level as possible, should be first laid of plaster, or of boards; if the latter, they should be of sufficient substance to prevent their warping, or flying upwards; for if this be not attended to, the lead will soon become unsightly, and be liable to crack. As the sheets of lead never exceed in their breadth above six feet, it becomes necessary, in covering large surfaces, to have joints, which are managed several ways; but, in all, the main object is to have them water-tight. The preferable mode is by forming *laps* or *roll-joints*, which is done by having a *roll*, or strip of wood, about two inches square, but rounded on its upper side, nailed under the joint of the sheets, where the edges lap over each other; one of these edges is to be dressed up over the roll on the inside, and the other is to be dressed over them both on the outside, by which means the water is prevented from penetrating. No other fastening is required than what is acquired from the hammering of the sheets together down upon the flat; nor should any other be resorted to, where sheet-lead is exposed to the vicissitudes of the weather, because they occasion it to expand and shrink, which, if prevented by too much fastening, would cause it to crack, and be quickly good for nothing but the melting-pot. Circumstances sometimes occur, that preclude the use of rolls, and then the method by *seams* is resorted to: this consists in simply bending the approximate edges of the lead, up and again over each other, and then dressing them down close to the flat, throughout their length. But this is not equal to the roll, either for neatness or security. Soldering is also sometimes had recourse to, for securing the joints; but this is not to be recommended, as lead so fixed will be sure to leak after an exposure to the sunshine of a single summer. Leaden flats and gutters should be always laid with a current, to keep them dry. A fall from back to front, or in the direction of the length of the sheet, is the general rule. A quarter of an inch to the foot run is a sufficient inclination: but the fall, or *current*, as it is called, is generally agreed upon between the carpenter and plumber, while the former is preparing the ground, or platform, on which the lead is to be laid.

In making gutters, &c., pieces of milled lead, called *flashings*, about eight or nine inches wide, are fixed in the walls all round the edges of the sheet-lead, with which the flat is covered, and are suffered to hang down over them, so as to prevent the passage of rain through the interstice between the raised edge and the wall. If the walls have been previously built, the mortar is raked out of the joint of the bricks next above the edge of the sheet, and the flashings are not only inserted into the crack at the upper sides, but their lower edges are likewise dressed over those of the lead in the flat or gutter. And when neither of these modes can be resorted to, the flashings are fastened by wall-hooks, and their lower edges are dressed down, as before.

Drips in flats, or gutters, are formed by raising one part above another, and dressing the lead as already described, for covering the rolls. They are resorted to when the gutter, or flat, exceeds the length of the sheet; or sometimes for convenience. They are also an useful expedient to avoid soldering the joints.

Reservoirs are generally made of wood, or masonry, for their exterior, and lined with cast sheet-lead, soldered at the joints. As these conveniences are rarely in places subject to material change of temperature, the soldering may be resorted to, without fear of its occasioning damage to the work, by promoting a disposition in the lead to crack.

The plumber's employment in pumps is confined generally to two or three kinds, required for domestic purposes, of which the suction and lifting pumps are the chief; these, as well as water-closets, are manufactured by a particular set of workmen, and sold to the plumber, who furnishes the lead pipes, and fixes them in their places.

Plumber's work is commonly estimated by the pound or hundred-weight; but the weight may be discovered by the measure of it, in the manner below stated. Sheet-lead used in roofing, guttering, &c., is commonly between seven and twelve pounds weight to the square foot; but the following table shows the particular weight of a square foot for each of the several thicknesses.

Thickness.	Pounds to a Square Foot.	Thickness.	Pounds to a Square Foot.
.10	5.899	.15	8.848
.11	6.489	.16	9.438
$\frac{1}{9}$	6.554	$\frac{1}{6}$	9.831
.12	7.078	.17	10.028
$\frac{1}{8}$	7.373	.18	10.618
.13	7.668	.19	11.207
.14	8.258	$\frac{1}{5}$	11.797
$\frac{1}{7}$	8.427	.21	12.387

In this table the thickness is set down in tenths and hundredths, &c. of an inch; and the annexed corresponding numbers are the weights in avoirdupois pounds, and thousandth-parts of pound. So the weight of a square foot of $\frac{1}{10}$ of an inch thick, or $\frac{10}{100}$, is 5 pounds, and 899 thousandth-parts of a pound; and the weight of a square foot to $\frac{1}{9}$ of an inch thickness, is 6 pounds and $\frac{554}{1000}$ of a pound. Leaden pipe of an inch bore is commonly 13 or 14 pounds to the yard in length.

The plate exhibits the various forms of joining the lead at the concourse of an external angle made by a flat at the top, and one of the sloping sides of the roof; also, the method of joining the sheets between opposite extremities to which the joints or seams run parallel.

Figure 1. No. 1.—The first part of the operation of joining two sheets both in the same flat or plane. D A and E G are supposed to be portions of the flat joining together at A G, where each is bent to a right angle, D A B and E G F; the part, A B, which rises upwards, exceeds the part G F, in contact by C D, which is about one-third.

No. 2 explains the second step of this operation, exhibiting the part, G F, bent over the end D, perpendicular to the horizon.

No. 3 is the third step, and shows the part, D F, No. 2, bent so as to be parallel to the horizon, and consequently coincident with the surface, C D, of the upper part; and, so far as this operation has gone, it is the same as the first.

No. 4 exhibits the entire finish or last step of the operation.

The other method is by a roll of wood fixed over the upright part, which descends downwards to cover the slates, and is exhibited in *Figure* 3, Nos. 1, 2, 3, 4, 5, 6, which are sufficiently plain to inspection, from what has been explained of *Figures* 1 and 2.

PLUMMET, Plumb-Rule, or Plumb-Line, an instrument used by masons, carpenters, &c. to draw perpendiculars, in order to judge whether walls, &c. be upright, planes horizontal, and the like.

Its name is derived from a piece of lead, *plumbum*, fastened to the end of a thread or chord, which usually constitutes this instrument.

Sometimes the string descends along a ruler of wood or metal raised perpendicularly on another; in which case it becomes a level.

At sea, a plummet is used by the pilot to sound the depth of the water.

PLUTEUS, the wall which sometimes closes the intervals between the columns of a building. The term is also applied to the podium intervening between two orders of columns placed one above another.

PLYERS, in fortification a kind of balance used in raising or letting down a draw-bridge. They consist of two timber levers, about twice the length of the bridge they lift, joined together by other timbers framed in the form of a St. Andrew's cross, which serve as a counterpoise. They are supported by two upright jambs, on which they swing; and the bridge is raised or let down by means of chains joining the ends of the plyers and bridge.

PLYMOUTH MARBLE, a sort of marble dug in great plenty about Plymouth, and in some parts of Devonshire, where it lies in very thick strata, from whence it is carried to London in large quantities; and, when wrought, looks little less beautiful than some of the Italian marble.

It is very hard and firm, and of a beautiful texture; its ground is of blueish-white, and its variegations are principally a pale red, and in smaller quantities brown and yellow: these lie in very orderly beds, and there is often a very agreeable glow of a faint red diffused through the whole substance. It is remarkably even in its whole structure, and is therefore capable of a more than ordinarily elegant polish.

PODIUM (Latin), a continued pedestal, or plinth, serving to support a colonnade: it consists of a plinth, base, die, and corona. It is sometimes made to break forward under each column, such projection being distinguished by the name of *stylobate*. Also, in the theatre of the ancients, the wall that separated the orchestra from the scene.

POINT (from *punctum*, formed from *pungere*, *to prick*), a term in various arts.

Point, *Accidental*, a term used by the old writers on perspective, instead of *the vanishing point*, adopted by Brook Taylor. Accidental points were the vanishing points in the horizontal line, and were thus found:—The representation of two original points being obtained, a line was drawn through them both, and produced to meet the vanishing line of the horizon, and the intersecting point was called *the accidental point*, which served to draw all other lines, whose originals were parallel to the first. The method given by Dr. Brook Taylor is, however, much more direct; as the vanishing point is found by a geometrical process, viz., by drawing a straight line through the eye, parallel to an original line, which serves likewise for the vanishing point of all its parallels.

Point, in geometry, according to Euclid, is a quantity which has no parts, or which is indivisible. Wolfius defines it, that which terminates itself on every side; or which has no terms or boundaries distinct from itself. This is what we otherwise call *the mathematical point*, and is only conceived by the imagination; yet it is in this that all magnitude begins and ends, the flux or motion of the point generating a line, that of a line a surface, &c. Hence, some define a point to be the inceptive of magnitude. Hobbes defines a point to be a body whose magnitude is not considered; but his false notions of a point, line, and surface, have led him into many errors. Monsieur de Crouzas also has supposed a line to be composed of points in his *Geometry*, and in his comment on the *Analyse des Infiniment Petits*. One line can cut another only in a point. Any three points being given out of a right line, a circle, or part of a circle, may be drawn, that shall pass through them all.

Point, in perspective, a term used for various parts, or places, with regard to the perspective plane.

Point, in physics, the smallest or least sensible object of sight, marked with a pen, point of a compass, or the like.

This is what we popularly call *a physical point*, which, in reality, has parts, though those parts are not here regarded. Of such points does all physical magnitude consist.

This physical point coincides with what Mr. Locke calls *the point sensible*, and which he defines to be the least particle of matter, or space, we can discern. He adds, that, to the sharpest eye, this is seldom less than thirty seconds of a circle, of which the eye is the centre.

Point, *Conjugate*, is used for that point into which the conjugate oval, belonging to some kinds of curves, vanishes.

Point, *Objective*, a point on a geometrical plane, whose representation is required on the perspective plane.

Point of Contrary Flexures, in the higher geometry, the point of a curve wherein it is inflected to a part contrary to that to which it originally tended.

Point of Distance, in perspective, the distance of the picture, transferred upon the vanishing line from the centre, or from the point where the principal ray meets it; and thus it is generally understood to be on the vanishing line of the horizon.

Point of Reflection, in geometry, is commonly used instead of *point of retrogradation*, or *retrogression*.

Point of Sight, the place of the eye whence the picture is viewed, according to the definition of Dr. Brook Taylor; but, according to the old writers on perspective, the point of sight is what Brook Taylor denominates *the centre of the picture*.

Point of View (the same as *the point of sight*) is the situation of the eye of the spectator when viewing an object to be represented in a picture.

Point, *Visual*, see Visual.

POINTED ARCH, an arch pointed at the top, resembling the point of a lance. *See* Architecture.

POINTED ARCHITECTURE, that style of architecture which originated in the substitution of the pointed for the

semicircular arch, and which began to be employed in the early part of the twelfth century. The pointed arch is formed by the intersection of two segments, which in the earlier examples are very flat, and form very acute arches; but in the later periods are of quicker curvature, and the arches in consequence proportionately depressed. The pointed arch, however, although the main feature in the style, does not form its only peculiarity; but in principle as well as in matters of detail, the style is peculiar and distinct from every other. This subject has been fully discussed under the article Gothic Architecture, a name which the style has assumed in common with the above and many others. It is our intention in this place to consider only the origin of the style and the manner of its development. On this subject we are left almost entirely to our own resources, no manuscripts being known to exist which give us any information respecting it, nor are we acquainted with even the names which the Gothic architects employed to designate the different divisions of their style. As regards the architects themselves, too, and the precise date of the buildings erected by them, we are left much in the dark; and whatever conclusions may have been arrived at, have been founded on little better than conjecture. Many archæologists, architects, and others interested in the question, have treated upon the subject, and have eliminated a great deal of useful information by their researches, although not one of them can be said to have come to a conclusive or satisfactory result regarding the question immediately before them. Many theories have been broached by different writers, some of which are plausible, and others little better than ridiculous; none are so perfect as to obtain universal assent, nor is it to be expected under the circumstances that they should be so. It is perhaps owing to the uncertainty necessarily attending the research, that the subject has been so fashionable amongst antiquaries; but however unsatisfactory their inquiries may have been as regards the matter in dispute, we must not forget that it is in all probability to such inquiries we owe our present knowledge on the subject, and the present appreciation of the style. Our very want of information as to its origin has probably been rather an advantage than otherwise, for we have been compelled thereby to search into the matter, and seek knowledge from every quarter; whereas had the question been easy of decision, all the information which we have obtained in this manner might have been lost to us.

Of the many theories which have been started, we shall here take notice of some of the more prominent, commencing with such as require but little comment, and proceeding in those which seem entitled to some further consideration. Bishop Warburton, one of the writers on the subject, discovers the prototype of a Gothic cathedral in a grove of trees, such an imitation having been employed, as he supposes, from the circumstance of the Celts being accustomed to worship in such places, and from their early associations having introduced the same forms in their constructed temples. The trunks of the trees are supposed to be represented by the pillars, and the overhanging branches by the ribs of the vaulting. The same opinion is said to have been entertained by Raphael d'Urbino; but we venture to say that the resemblance between a Gothic aisle and an avenue of trees is not at first sight very striking, and that the idea is rather in accordance with the imagination of the poet than the researches of the antiquary. It makes somewhat against this theory, that all evidence goes against the introduction of the Pointed style by the Goths, and also that the closest resemblance is to be found in the later, and not in the earlier examples. It is not improbable that Warburton himself felt dissatisfied with this notion, for it is not known to exist in more than one edition of his commentary on Pope's works, though later editions were published during his lifetime.

Similar to the preceding is the opinion entertained by Sir James Hall, who, with equal felicity of imagination, refers us to interlaced wicker-work as the undoubted prototype of the Pointed style in all its parts—its groined roofs, clustered pillars, and traceried windows; and thus Gothic churches become representations of the primitive churches in this island. Sir James has taken upon himself no inconsiderable amount of labour in his endeavour to prove his theory the correct one, and has profusely illustrated his book to show how precise is the imitation; but his illustrations, as well as his argument, go to prove the converse of his proposition, not that Gothic architecture took its origin from interlaced twigs and branches, but only that wicker-work may be made to assume the forms frequent in that style. The same argument respecting the similarity being most conspicuous in the later examples, exists also in this instance.

Mr. Murphy, well known by his publications on the architecture of Spain, refers us to the pyramids of Egypt as the grand type of the style; and in his splendid work on the church of Batalha, after having stated the tendency of every ornament to the general pyramidal form, says—"It appears evident from this instance, that the pyramidal form actually exists throughout the several component parts, and the general disposition of the edifice approaches as near to it at least as the ordonnance of an historical painting which is said to be pyramidally grouped. Hence we may comprehend the reason why the arch was made pointed, as no other forms could have been introduced with equal propriety in a pyramidal figure, to answer the different purposes of uniformity, fitness, and strength; it is in vain, therefore, that we seek its origin in the branches of trees, or in the intersection of Saxon or Grecian circles, or in the perspective of arches, or in any other accidental or fortuitous circumstances. The idea of the pointed arch seems clearly to have been suggested by the pyramid, and its origin must consequently not be attributed to accident but to ordination." That there may be some truth in this theory as regards the pyramidal grouping of these buildings we are not prepared to deny; but neither are we prepared to assert that the principles of Pointed architecture were therefore derived from the pyramids of Egypt. A contemporary has given the following somewhat amusing critique or illustration of the arguments brought forward by Mr. Murphy. "The pyramids of the Egyptians are tombs; the dead are buried in churches, and on their towers pyramidal forms are placed; consequently the pyramids of the towers indicate that there are graves in the churches; and as the pyramidal form constitutes the essence of the Pointed-arch style, and the pyramids of the towers are imitations of the Egyptian pyramids, the pointed arch is derived from the latter."

Some authors are anxious to discover the prototype in a framed timber building, but in what the resemblance exists it is somewhat difficult to determine. The late Mr. Barry attributes the Gothic style to the corruption of Greek and Roman art; Mr. Dallaway, to the desire of novelty and the caprice of the Italians. Lord Orford perceives the prototype in shrines for reliques, and observes, "it was a most natural transition for piety to render a whole church as it were one shrine:" he adds, "the Gothic style seems to bespeak an amplification of the minute, not a diminution of the great." Of the first two, Mr. Barry and Mr. Dallaway, we are inclined to think that both are, to a certain extent, correct, that Pointed architecture was a gradual development of the principle of the arch, and that taking it as a whole it does owe its origin

to the Romanesque or Debased Roman, in a similar manner as the Roman was, in a degree, an imitation of the Grecian orders. That it owes its existence also—at least partially—to a desire for novelty, we are not in a position to contradict; but that it originated in Italy, we consider a matter of very great improbability. Dr. Whittaker, with whom Mr. Whewell somewhat agrees, is of opinion that pointed arches were known to, and practised by, the Romans during the empire, and originated in the intersection of cross-vaulting, examples of which are to be seen in the palace of Diocletian, at Spalatro. This suggestion is very worthy of consideration, and is, at least, a method by which the pointed arch was constructed, and that, too, accidentally, as it were, and in regular course. Vaulting, we know, was employed by the Romans, and, as a matter of necessity, cross-vaulting succeeded; and in some cases, by such a system, the pointed arch was described in the process. It is not unlikely that this circumstance should have been noted, and turned to practical advantage.

In connection with this should be considered an hypothesis, which has been held by Dr. Milner, Mr. Bentham, and several others, and which has met with a considerable share of public favour. Their supposition is that the pointed arch has been suggested by the intersection of semicircular arches. That interlaced arches were largely employed in Norman architecture as a means of decoration, there can be no question, and that, too, previous to the introduction of the pointed arch. That pointed arches were thus formed by the intersection is equally certain; nor is it at all improbable that the idea may have suggested itself thereby. Still this solution of the question is not unattended with difficulty or objection. In the first place, Dr. Milner is evidently incorrect in attributing its invention to Henry of Winchester, for it is known that the abbey of Clugny, in France, where he himself had been monk, was constructed with pointed arches; and therefore it is more reasonable to suppose that he had copied the idea from that building, rather than have invented it from his observation of the form in the intersection of semicircular arches. But laying aside this objection, which applies only to a peculiar and individual instance, and considering the theory simply on its own merits, we cannot consider it perfectly satisfactory; for it is somewhat improbable that the leading feature of the style should have had its origin in an accidental and unessential matter of detail; that a grand principle of construction should have been eliminated from a mere method of decoration.

Some authors have asserted that the style was invented by the Goths; whether the term Gothic formed the principal ground for such an assertion, it is not easy to determine; but it is very certain that no reason can be assigned for it which would have much greater weight than even this; for as regards this people, we have no reason to suppose that they possessed any style of architecture of their own, but rather the reverse; and although their king, Theodoric, did erect some buildings, they were constructed in the same style as the structures already existing in the country. It is true that Gibbon, in his Fall of the Roman Empire, states that the representation of Theodoric's palace at Verona, still extant on a coin, supplies the oldest and most authentic model of Gothic architecture; but in the work to which he refers for an engraving of this coin, we find none, indeed, of a coin, but one of a seal; the building represented on which is in a totally dissimilar style. One conclusive argument, however, against this theory, consists in the fact, that no building of this style has ever been known to exist which can claim so great an antiquity as that desired to be established by this statement; and, moreover, that the Gothic style was not introduced into Italy till a comparatively late period, when the Goths had been long since forgotten, and, indeed, never obtained a permanent footing in that country.

Other writers, with greater show of reason, have derived our knowledge of this style from the Saracens, supposing it to have been brought over by the Crusaders; nor is such an opinion taken up without good grounds, as it meets some grand difficulties which others are subject to, and yet is in many points unsatisfactory. As regards its chronology this theory is fortunate; for it certainly was about the time of the Crusades that the style became prevalent; while yet, on the other hand, there is good evidence to suppose that one or two buildings of the kind existed in Europe before any of the Crusades had taken place. Another circumstance in its favour is, that it is the only supposition which will account satisfactorily for the simultaneous adoption of the style throughout Europe; a circumstance which, in all the other ideas which have been broached, forms an insurmountable objection to their acceptance. Whether the pointed arch was common in Saracenic buildings of the time, has been a matter of endless discussion; nor does it seem to have ever been satisfactorily proved or disproved, owing to a want of accurate information, and uncertainty as to the date of existing examples. There seems reason to believe that the pointed arch did exist, but was not so prevalent as some would have us suppose, or at least not in that form in which we find it in Europe; but whether pointed arches were to be found or not, is not a matter of such consequence as some would make it; nor does it of necessity prove anything; for we know that this form is to be found occasionally in ancient buildings of other countries, from which no one has attempted to deduce its introduction into Europe. But even supposing the styles to assimilate as regards the pointed arch, they agree in no other principle; in the buildings of the Saracens, we find neither cross-vaulted roofs nor arcades forming nave and aisles, nor clustered columns, nor crocketed pinnacles, nor towers, nor spires: their mosques are mostly square on plan, and are conspicuous chiefly for their bulbous domes, the nearest approach to the Gothic spire being found in the minarets. The idea of Gothic window-tracery is said to have been derived from the perforated fret-work of Arabian architecture; but if so, it must be recollected that such tracery is only to be found in the later examples when the style was fully developed; and, moreover, that we have a more satisfactory mode of accounting for its introduction. The above theory is supported by Warburton, Warton, Whittington, Lord Aberdeen, and Sir Christopher Wren; the last author, however, seems to prefer the supposition of the introduction of the arch into Europe by the Moors of Spain, but for this opinion there does not appear to be anything like the amount of evidence which may be produced in favour of the former. Other writers prefer to give the honour to the Visi-Goths of Spain, rather than to their Arabian invaders, but apparently with little better reason.

We have now taken a cursory glance at most of the leading theories respecting the introduction of the pointed style into Europe; but, as we have seen, not one of them is free from objections of considerable importance. One main objection, which affects nearly all of them, is this, that instead of the resemblance to the supposed prototype being, as it ought to be, the closest and most exact in the first stages of the style said to be derived from it, the resemblance is there least of all discernible. There is another objection, which touches every one of them—they all seem to rest satisfied when they have found, or thought they have found, the origin of the pointed arch, forgetting that this does not comprise the entire question at issue; their only inquiry appears to have been as to wh

were the inventors of the pointed arch, and not of pointed architecture. Now, there is a vast difference between the two questions, for the former embraces but a fractional part of the latter: a pointed arch is but a component part, and does not of itself constitute absolute Gothic architecture, although it is one and a very important characteristic of it. At the same time there are other peculiarities little less important; such are its principle of verticality; its lofty towers and spires; its cross-vaulting; its light and clustered pillars, with their slender shafts; its tracery, mullions, &c.; these are all necessary to make up a complete whole, and each and all ought to be considered in determining the origin of the style.

With such conflicting opinions as to the origin of the style, it is not to be expected that there should be any agreement as to what European country was the first to adopt it. The honour has been claimed for England, France, and Germany: the claim has been made for England by Sir Henry Englefield and Horace Walpole; but although the buildings of the style are to be found in this country in great number and variety, and are, on the whole, of greater purity, and in our opinion, of superior excellence, to those on the continent, still more satisfactory evidence has been elicited in favour of the latter. The late Mr. Hope, in his historical Essay on Architecture, has produced much able argument in favour of Germany; whilst Wetter, a writer of that country, contends that priority of date, as regards the adoption and development of the style, properly belongs to France. The claim has been made for Italy, but there seems to be little evidence to favour such an opinion; and Mr. Gally Knight, in his elaborate work on the ecclesiastical architecture of that country, gives good reason for disregarding it.

Notwithstanding the variety and antagonism of the opinions which have been started upon the subject, it is possible that more than one of them may be partially correct, because a variety of circumstances may have contributed more or less towards the same end; but we must confess that the change of style has not as yet been sufficiently accounted for. Whether the question will ever be determined beyond dispute, may fairly be questioned; nor do we know that any substantial advantage would be gained thereby. It is true, we are every day advancing to a more perfect knowledge of the style, and, in the course of our inquiries, some unexpected light may be thrown upon the subject; but be this as it may, it is certain that it will be much more advantageous to continue our practical study of the style, than to turn aside for the mere purpose of speculating on its origin.

POINTS, *Proportion of Mathematical.* It is a current maxim, that all infinities, whether infinitely great or infinitely small, are equal; yet is the maxim false in both cases. Dr. Halley shows several infinite quantities, which are in a finite proportion to each other; and some infinitely greater than others.

The like, the honourable Mr. Roberts shows of infinitely small quantities, viz., mathematical points. He demonstrates, for instance, that the points of contact between circles and their tangents, are in a subduplicate proportion to the diameters of the circles; that the point of contact between a sphere and a plane is infinitely greater than that between a circle and a tangent; and that the point of contact in spheres of different magnitudes are to each other as the diameters of the spheres.

POLISHING, the art of giving a gloss or lustre to a thing; particularly a precious stone, marble, glass, a mirror, or the like.

For grinding and polishing steel, the grindstones used are made to revolve, either vertically or horizontally, with a velocity so great as to describe sometimes as much as sixty feet in a second. The steel is also, in some cases, drawn backwards and forwards horizontally on a circular surface; and in order that the action may be equally distributed throughout the surface, it is allowed to revolve on an axis by means of the friction; its motion being confined to one direction by the action of a catch. Various substances, chiefly of mineral origin, are also used, on account of their hardness, as intermediate materials, for grinding and polishing others. These are diamond-dust, corundum, emery, tripoli, putty, glass, sand, flint, red oxyde of iron, or crocus martis, and prepared chalk. These are sometimes applied in loose powder, and sometimes fixed on wood, leather, or paper. Cuttle-fish bone and seal-skin are furnished by the animal kingdom; and Dutch rushes by the vegetable; these are employed chiefly in polishing wood or ivory. Marble is made smooth by rubbing one piece on another, with the interposition of sand; the polishing-blocks are sometimes caused to revolve by machinery in a trough, in which the marble is placed under water, and are drawn at the same time gradually to and from the centre; or the slab itself, with the frame on which in rests, is drawn slowly backwards and forwards, while the blocks are working in it. Granite is polished with iron rubbers, by means of sand, emery, and putty; but it is necessary to take care, during the operation, that the water, which trickles down from the rubbers, and carries with it some of the iron, may not collect below the columns, and stain them; an inconvenience which may be wholly avoided by employing rubbers of glass.

POLLARD, in planting, a term applied to a tree that has been frequently polled or lopped, and its top taken off, or headed down to the stem, for the purpose of fire-wood, or small poles for hurdle-wood, and other similar uses, as well as for hop-poles, &c. It is a term most commonly in use in the southern and eastern districts of the kingdom. But though much wood of this small sort may be provided in this way, the practice has been highly reprobated, not only as being destructive of good timber, but as a barbarous system which disfigures, and renders the appearance of the country disagreeable.

POLYCLETUS, a celebrated sculptor of antiquity, a native of Sicyon, who flourished about the year 430 B.C. He was supposed to have carried the art to the highest degree of perfection, at least as far as the excellence of single figures could go. One of his figures, representing a life-guard of the king of Persia, was performed in such exact proportions that it was called *the rule*, and artists came to study it as a model. He made the statue of a boy, which was estimated at a hundred talents (nearly 20,000*l.* sterling). The emperor Titus had two naked boys playing at a game, by his hand, which was considered as a perfect performance. It was peculiar to him, that he formed almost all his figures supported on one thigh, which made them appear deficient in variety.

POLYCHROMY (Greek *πογυς* and *χρῶμα*, colour), the art of painting in positive colours, either on flat surfaces or sculptured figures. It was much used by the Egyptians in their edifices, and they were probably the first to introduce such ornament. The Greeks adopted the same method of decoration, and improved upon it; as also did the Romans. There are still existing many specimens of the application of this art in the ruins of Herculaneum and Pompeii, the colours still retaining their brilliancy. The Arabs excelled in this art, as is evidenced by their edifices, which owe much of their peculiar beauties to the aid of colour. The interiors of their edifices are completely covered with polychromatic decoration, such parts of the walls as were not covered with actual painting being lined with coloured and glazed tiles. Polychrome was also in general use amongst our mediæval

architects, and the grand effect of their buildings was considerably heightened by such ornamentation. We regret that even in the present day any prejudices should be found to prevail against its introduction into our ecclesiastical buildings; we have, however, more than one of our recent churches in which such assistance has not been despised; and we feel sure that the contrast between such and the cold bare walls of the majority, will at length prevail against every prejudice. We are glad to be able to allude, also, to the restoration of this art to its proper position, in the instance of a public building such as the British Museum, and we trust that its success there will lead to its general adoption.

POLYFOIL, an ornament prevalent in Gothic architecture, formed of a moulding, disposed in a number of segments of circles, producing projecting points at their intersections, termed cusps: thus we have *trefoil*, consisting of three cusps; *quatrefoil*, of four; and *polyfoil*, of any number above four.

POLYGON (from πολυγωνος, formed from πολυς, *many*, and γωνια, *angle*) a multilateral figure, or one whose perimeter consists of more than four sides and angles.

If the sides and angles be equal, the figure is called a *regular polygon*. For *similar polygons* see SIMILAR.

Polygons are distinguished according to the number of their sides. Those of five sides are called *pentagons;* those of six, *hexagons;* those of seven, *heptagons*; those of eight, *octagons*, &c.

POLYGONS, *General properties of.* Euclid demonstrates the following:—1. That every polygon may be divided into as many triangles as it hath sides. 2. The angles of any polygon, taken together, make twice as many right angles, abating four, as the figure hath sides. Thus, if the polygon hath five sides, the double of that is ten; whence, subtracting four, there remains six right angles. 3. Every polygon, circumscribed about a circle, is equal to a right-angled triangle, one of whose legs is the radius of the circle, and the other the perimeter, or sum of all the sides of the polygon. Hence every regular polygon is equal to a right-angled-triangle, one of whose legs is the perimeter of the polygon; and the other a perpendicular, drawn from the centre to one of the sides of the polygon.

Hence, also, every polygon circumscribed about a circle is larger than it; and every polygon inscribed is less than the circle. The same likewise appears hence, that the thing containing is ever greater than the thing contained. Hence, again, the perimeter of every polygon circumscribed about a circle, is greater than the circumference of that circle; and the perimeter of every polygon inscribed, less; whence it follows, that a circle is equal to a right-angled triangle, whose base is the circumference of the circle, and its height the radius; since this triangle is less than any polygon circumscribed, and greater than any inscribed.

Nothing therefore is wanting to the quadrature of the circle, but to find a right line equal to the circumference of a circle.

The subjoined table gives the areas of polygons and their perpendiculars from the centre to one of the sides, the side being supposed equal to unity.

Number of sides.	Area.	Perpendiculars.
3	.433013	.2886751
4	1.000000	.5000000
5	1.720477	.6881910
6	2.598076	.8660254
7	3.633912	1.0382617
8	4.828427	1.2071068
9	6.181824	1.3737387
10	7.694209	1.5388418
11	9.365640	1.7028437
12	11.196152	1.8660254

To apply this rule generally, multiply the square of the side of the given polygon by the number found in the table of areas for a polygon, having the same number of sides as that whose area is required.

POLYGRAM, (Greek, πολυς, and γραμμα,) in geometry, a figure consisting of many lines.

POLYHEDRON, or POLYEDRON (from πολυεδρον, formed from πολυς, *many*, and ἑδρα, *side*,) a body comprehended under many rectilinear sides, or planes.

If the sides of the polyhedron be regular polygons, all similar and equal, the polyhedron becomes a regular body, and may be inscribed in a sphere; that is, a sphere may be drawn round it, so that its surface shall touch all the solid angles of the body.

POLYHEDROUS FIGURE, a solid contained under, or consisting of, many sides. *See* POLYHEDRON.

POLYSTYLE, (Greek, πολυς, *many*, and στυλον, *a column*,) a term applied to buildings which are surrounded by a multitude of columns.

POMEL, a boss or knob terminating a conical or dome-shaped roof.

POMPEII, an ancient city of Naples, overwhelmed in the first century by the same disastrous catastrophe which destroyed *Herculaneum*. It is said to owe its name to the triumphant pomp in which Hercules led his captives along the coast after his conquest of Spain; it was probably situate on an arm of the sea, and served as a port for the inland towns; which inlet of the sea has been filled up by successive eruptions, besides that which destroyed the town. It is about fourteen miles from Naples, on the road to Nocera. From Naples to Torre del Greco, the highway is almost a street, so close are the villas, villages, and towns to each other. As the road runs along the coast, and at the foot of Vesuvius, every break gives on one side a view of the bay, on the other of the mountain. Torre del Greco still presents, in its shattered houses, half-buried churches, and streets almost choked up with lava, a melancholy instance of the ravages of the eruption. The depth of the destructive torrent is, in some places, twenty-five feet, so that the entrance into several houses is in the second story, and into one church through the great window over the western door. Some edifices were entirely destroyed: others were surrounded, incrusted, and filled with lava, and may perhaps give a very accurate idea of the state of Herculaneum at the time of its destruction. The town of Torre del Greco was supposed, by Cluverius, to occupy the site of Herculaneum, because the distances nearly corresponded; and inscriptions have been found that seem to corroborate this conjecture. In fact, making allowances for the extent of the ancient town, there is little more than three-fourths of a mile difference, so that its name and jurisdiction extended probably much farther. In the vicinity of this place are the ruins of ancient barracks, which were the quarters of a legion of Roman soldiers, and behind the barracks are two theatres, one small, and supposed to have been covered, the other large; both these edifices were lined with marble, beautifully paved, and in every respect highly-finished. These theatres are exactly of the same form as the Teatro Olimpico of Palladio at Verona; having, like it, a narrow proscenium, and three entrances, one large and the other two less, to the stage, from the scenery behind. These theatres, when discovered, were nearly entire, but though they have been stripped of all their decorations, they still retain all their great characteristic features. Behind the little theatre is a temple of Isis, occupying an angle formed by two streets. Some have supposed that oracles were issued from this temple, and have declaimed against the priestcraft that was practised here; but it does not appear that oracles were e er

given at Pompeii, as this was a privilege reserved to the ancient and more renowned temples; besides, oracles had everywhere ceased before this edifice, or temple, if it may be so called, was erected; and, moreover, the entrances into it are too public, and the whole contrivance too gross to dupe the dullest peasant, much less the polished inhabitants of Pompeii. In this building there are niches, where various statues of Venus, Priapus, &c., were found, which, with the furniture, marble, and pictures, were transported to Portici. Behind this temple, on one side, is a court surrounded with a portico, supported by sixteen Doric pillars, and, from a sort of pulpit on one side, it may be inferred, that it was intended for some public assembly. Another court follows with a similar portico, and communicates with the grand portico of the theatre supported by more than sixty stone pillars of the Doric order, but, in proportion, bordering upon Tuscan. Near this portico lie several fragments of columns of a much larger size, and of bolder proportion; which, perhaps, belonged to the temple of Neptune, and may have been thrown down and laid in their present situation by the earthquake, which nearly destroyed this city a few years previous to the eruption that buried it finally. The most perfect and most curious object that has yet been discovered is a villa at a little distance from the town. It consists of three courts; in the first and largest is a pond, and in the centre an ædicula, or little temple: there are numerous apartments of every description, paved in mosaic, coloured and adorned with various paintings on the walls, all in a very beautiful style. The baths in this villa seem to have been objects of particular attention.

Cicero's Pompeianum stood in the neighbourhood of this town, and possibly on this very spot. It was a favourite retreat, much frequented by Cicero and his friends. The houses at Pompeii are on a small scale, generally of one, sometimes of two stories; the principal apartments are always behind, enclosing a court, with a portico round it, and a marble cistern in the middle; two had glass windows, in the others shutters only were used; the pavements are all mosaic, and the walls are stained with mild colours; the decorations are bassorelievos in stucco, and paintings in medallions. Marble seems to have been common. An extent of about 500 feet of the town wall has been completely cleared. It is from eighteen to twenty feet high, twelve thick, and fortified at short distances with square towers. In the main street, passing in front of the temple of Isis, has been discovered the portico of the theatre. Near the same spot, ten feet below the level of the street, was found a human skeleton, and immediately beneath it a large collection of gold and silver medals in the finest preservation, chiefly of the reign of Domitian. Under a superb portico, in the quarter of the tombs, a number of skeletons have been discovered, and among them those of a female and several children. Three finger-rings and several ear-rings were found among the bones. Among the vases discovered, there were two which were full of water, with a small quantity of ashes at the bottom. In one the water was limpid and odourless; in the other it was of a brownish tinge, and had the taste of lye.

POMPEION, a stately edifice at Athens, in which were kept the sacred utensils made use of at festivals, and where all things necessary for the solemn processions were prepared. It stood at the entrance of the old city, which looked towards Phalerum, and was adorned with many statues of the Athenian heroes. This word was likewise used for any utensils employed on these occasions.

POMPEY'S PILLAR. *See* PILLAR.

POPPY HEAD, a carved ornament used as a terminating ornament at the top of the standards of ancient church-benches. The designs of such ornaments are not confined to one particular form, as the name might appear to signify, but were most frequently in the form of a finial composed of foliage of various kinds, grotesque figures, crests, and various other devices.

PORCH, (from the Latin, *porticus*) a kind of vestibule, supported by columns, much used at the entrance of the ancient temples, halls, churches, and many other buildings. *See* ATRIUM.

In the ancient architecture, a porch was a vestibule, or a disposition of insulated columns, usually crowned with a pediment, forming a covert place before the principal door of a temple, or court of justice.

When it had four columns in front, it was called a *tetrastyle;* when six, *hexastyle;* when eight, *octostyle;* when ten, *decastyle*, &c. Vitruvius calls it *pronas;* Pollux προδομος, *prodomos:* when finer than ordinary, the ancients call it, also, *propyleum.*

Porches are almost universal in churches, and are usually on the south side, and in the second bay from the west, but the position is frequently determined by the circumstances of the locality.

Norman porches are frequently of large dimension, and highly enriched with the ornament peculiar to that period; many such have been preserved in buildings which in other respects have been entirely rebuilt in a later style. Many fine porches of this kind are to be found at Malmesbury, Sherbourne, and Southwell, the last having a room over it; there is also a very fine one at the Temple Church, London. Early English specimens occur at Wells, Salisbury, Lincoln, and Westminster; and the examples in this as well as in the Norman style, are almost invariably of stone. Decorated and Perpendicular porches are frequently of wood, sometimes entirely closed at the sides, but more often of open work, and with ornamental barge boards at the end of the roof; many very beautiful specimens are to be found of both styles.

A few Galilee porches exist in some of our cathedrals. *See* GALILEE, and CATHEDRAL, also CHURCH.

PORPHYRY, (from πορφυρος, *purple*) a denomination that distinguishes a large class of primitive rocks, composed of one substance, in the form of grains, or crystals, imbedded in another, consisting most commonly of a compact paste, as its basis. The base is clay-stone, horn-stone, compact felspar, pitch-stone, pearl-stone, or obsidian; the implanted grains, or crystals, are of quartz, or felspar. Of porphyry there appear to be two formations; the most ancient consists principally of horn-stone and felspar porphyry, and the most recent are of clay, pitch-stone, pearl-stone, and obsidian porphyry. The porphyritic formation is not very distinctly separated from the other rock formations which accompany it, nor is its rank among the primitive mountains, with regard to antiquity, very clearly ascertained. The mountains of porphyry are not stratified, and never enclose beds of other substances. Its texture is commonly compact, but it occasionally occurs in schist-stone. It is not very rich in mineral veins; the clay porphyry is the most rich. The mines of Schweitz, in Hungary, which are of this description, are found in this species of rock.

Some writers have reckoned five species of rocks belonging to the proper porphyritic formation, which are as follows: viz., 1, *Horn-stone porphyry*, the base of which, being horn-stone, is generally red or green, with a conchoidal, or splintery fracture; and enclosing crystals of quartz and felspar. This is also distinguished, says Kirwan, by its hardness, slight transparency, and want of lustre; it is fusible without difficulty. Sometimes the felspar is decayed, and sometimes

also the horn-stone, whilst the quartz and hornblende remain entire: the whole thus acquires the appearance of indurated volcanic ashes, though the quartz might prove the contrary: if the felspar alone be decayed, the horn-stone will appear porous, and may be taken for lava. Its transitions are into granite and sand-stone. 2. *Felspar porphyry*, the base of which is commonly red compact felspar, enclosing crystals of felspar and quartz. 3. *Sienitic porphyry*, which differs from the preceding in containing crystals of hornblende in addition to the other ingredients. 4. *Pitch-stone porphyry*, the base of which is pitch-stone, either red, green, brown, gray, black, or yellow, of various shades, having generally many colours at once in the same specimen. According to Kirwan, this porphyry has the following characters: lustre, greasy, 2.1: transparency, 2.1: fracture, imperfectly conchoidal: hardness, 8, 9, 10: the felspar often blue: the fracture of some is slaty, and colour yellowish-gray: lustre, scarcely 1; transparency, 1; hardness, scarcely 9; specific gravity, 2.452. 5. *Clay porphyry*, the base of which is indurated clay, passing into horn-stone; generally of a reddish colour, and containing crystals of quartz and felspar. The colour of this porphyry, belonging to Kirwan's argillaceous porphyries, is generally some shade of gray, or greenish-gray, or brown, or blackish or reddish-brown, or isabella-yellow. Lustre and transparency, 0; fracture, earthy; hardness, from 5 to 7; sometimes adhering to the tongue.

PORTABLE BRIDGE. *See* Bridge.

PORTAIL, the face or frontispiece of a church, viewed on the side in which is the great door. Also, the great door, or gate itself, of a palace, castle, &c.

PORTAL, (perhaps a diminutive of the French, *porte*, door, gate,) a term used for a little square corner of a room, cut off from the rest of the room by the wainscot; frequent in ancient buildings, but now disused.

Portal is sometimes also used for a little gate, *portella*; where there are two gates of a different size: also, a kind of arch of joiner's work before a door.

PORT-CRAYON, (French) a pencil-case, an instrument serving to enclose a pencil, and occasionally also used as a handle for holding it. It is usually four or five inches long, and contrived so that the pencil may be slid up and down by means of a spring and button. Its outside is filed into eight sides or faces, on which are sometimes drawn the sector lines: its inside is round; sometimes it is made round or cylindrical, both without and within, and has its length divided into inches and parts of inches.

PORTCULLIS, (from the French *portecoulisse*) called also *herse* and *sarrasin*, an assemblage of several great pieces of wood, laid or joined, across one another, like a harrow, and each pointed at the bottom with iron.

These were formerly hung over the gateways of fortified places, to be let down in case of a surprise, when the enemy should come so quick as not to allow time to shut the gates. But now the orgues are more generally used, as being formed to answer the purpose better.

PORTICI, a small town of Italy, about six miles from Naples, on the sea-shore, at the foot of Vesuvius. Its principal ornament is a royal palace. Under this town and palace lies buried, at the depth of 70 feet under accumulated beds of lava, the city of Herculaneum, the first victim of the fires of Vesuvius. The Prince d'Elbœuf, after the first discovery was made by accident, purchased the spot, and continuing the excavations that had been begun, discovered various statues, pillars, and even a whole temple of the finest marble, adorned with statues. Upon the interposition of the Neapolitan government, the work was stopped for twenty years; however, the excavations were occasionally continued, and a basilica, two temples, and a theatre, were successively discovered, and stripped of their numerous pillars and statues Streets were observed, that were paved and flagged on the sides, and private houses, and even monuments, explored. A prodigious number of statues of bronze, of different sizes, pillars of marble and alabaster, and paintings and mosaics, many of them entire and in high preservation, others fractured and damaged, have been drawn from the edifices of this subterraneous city, and give a high idea of its opulence; to these we may add many species of ornaments used in dress, of weapons and armour, of kitchen utensils and domestic furniture, of agricultural and chirurgical instruments. The theatre is at present the only part open to inspection. Of all the articles drawn from Herculaneum, the most curious and valuable are the MSS. Of these many dissolved into dust as soon as they were exposed to the air: while others, though scorched, or rather burnt, resist the action of that element. The number of the latter, it is conjectured, may be about 1800.

PORTICO, (from the Latin *porticus*, a gate) a kind of gallery on the ground; or a piazza encompassed with arches supported by columns. The roof is usually vaulted, sometimes flat. The ancients called it *lacunar*. *See* Lacunaris.

The most celebrated porticos of antiquity were those of Solomon's temple, which formed the atrium, or court, and encompassed the sanctuary: that of Athens, built for the people to divert themselves in, and where the philosophers held their disputes and conversations; which occasioned the disciples of Zeno to be called *stoics*, from the Greek στοα, *porticus*; and that of Pompey at Rome, consisting of several rows of columns.

Plate I.—Plan and elevation of the Doric portico at Athens.

Plate II.—Portico of the Ionic temple, on the Ilissus at Athens.

Porticos were numerous buildings in Rome for the convenience of the public in sultry or inclement weather; distinguished from those which formed the vestibules, or which decorated the entrance of temples. Some of the principal were the *porticus duplex*, so called from its double row of pillars, erected by Cneius Octavius, near the Circus Flaminius, after the defeat of Perses; it was of the Corinthian order, and ornamented with brazen capitals; the walls were decorated with paintings representing the achievements of the founder. The *portico of Pompey*, annexed to his theatre, was supported by 100 marble columns; opened on both sides into groves of plane-trees, was refreshed by fountains and streams, and, in summer time, was the favourite resort of the young, the gay, and the gallant. Augustus erected several porticos; and, prompted by his example, many of his most distinguished and opulent friends vied with each other in similar works of magnificence. Among the former were the porticos of Caius and Lucius, with a basilica annexed to it; that of Octavia, which rose near the theatre of Marcellus, and contributed not a little to its beauty as well as convenience; that of Livia, near the Roman Forum. This latter was ornamented with a collection of ancient pictures, and shaded by a vine of prodigious luxuriance. Ovid alludes to it in his usual lively manner. But this, and every edifice of the kind prior to this æra, was eclipsed by the splendour of the *Palatine* portico, dedicated to Apollo. It was supported by pillars of Numidian marble, enlivened with exquisite paintings and statues, and emblazoned with brass and gold. It enclosed the library and temple of Apollo, so often alluded to by the writers of the Augustan age, and was deservedly ranked among the wonders of the city. It is

described by Propertius, lib. xi. 81. Another portico, erected by this emperor, was called *Ad Nationes*, from the statues with which it was furnished, representing various nations in their respective habits. It was, perhaps, still more remarkable for a statue of Hercules, lying neglected on the ground, though it had been brought from Carthage, and was that to which the Carthaginians were accustomed to offer human victims. The *Porticus Septorum* was finished, or repaired, by Agrippa, as Pliny says, and enclosed not the *Septa Tribata Comitii*, where the people assembled to vote, but *Diribitorium*, or place where the legions were mustered and paid. These edifices were all of marble, and the latter, in particular, unusually magnificent. Agrippa also built and gave his name to another portico, which, as some suppose, was connected with the present portico of the Pantheon, and carried around it. But as he had erected *Thermæ*, and other noble fabrics near that edifice, it is more probable that his portico enclosed the whole, and united them together in one grand circumference. That it was extensive, is evident from Horace, who represents it as a public walk, much frequented. The materials were, as in all Agrippa's works, rich marbles, and the ornaments, paintings and statues. The portico of *Hercules*, or of *Philippus*, was so called because it was rebuilt by the latter at the instigation of Augustus, and dedicated to Hercules, whose temple it enclosed, under the appellation of *Musagetos*, a leader of the Muses. It was erected solely for the ornament of the city, and of course was decorated with an unusual profusion of splendid objects; the paintings of Apelles, Zeuxis, and Antiphilus, forming part of its furniture. Several porticos took their names from the temples to which they were annexed, and seem to have formed either vast squares or courts before, or immense galleries round their respective temples, thus detaching them from ordinary buildings, and giving them a distinguished and solitary grandeur. The porticos of *Quirinus* and *Europa*, are mentioned by Martial as fashionable places of resort, and must consequently have been very spacious. That of *Isis* was remarkable, not only for paintings but mosaics.

The approach to the curiæ, the basilicæ, and the forums, were generally by porticos; several ranges of porticos led to the capitol, and lined the sides of the declivity; the Campus Martius was surrounded by an uninterrupted colonnade; almost every emperor distinguished himself by the erection of a new edifice of the kind; and Nero is said, by Suetonius, to have lined the streets of Rome (those probably which he himself had rebuilt) with a continued portico. Several porticos were erected by later emperors, of astonishing extent; such were that of Gallienus, extending nearly two miles along the Via Flaminia; and that of Gordian in the Campus Martius, which was a mile in length, and formed of one range of pilasters and four of columns, opening upon plantations of box, cedar, and myrtle.

PORTLAND STONE, (*Saxum Arenarium Portlandicum*, of Da Costa, and *Psadurium Hebes*, *Albidum*, *Laxius*, of Hill), an alkaline sand-stone, of a dull whitish colour, heavy, moderately hard, of a somewhat flat texture, and composed of a large roundish grit, cemented together by an earthy spar, and intermixed with numerous glittering spangles of pure spar; the grit splits in the cutting of the stone, so that it is capable of being brought to a surface very smooth and equal; it will not strike fire with steel, and burns to a slight ashen hue. The Portland stone belongs to the third variety of the compact limestone, under the calcareous genus, whose fracture is earthy, according to Kirwan's arrangement. Its specific gravity is 2.461. There are vast quarries of it in the island of Portland, in Dorsetshire, whence its name. It is brought from thence in large quantities to London, and is much used in building. This and all similar sorts of stone, composed of granules, and not of a laminated texture, will cut and rive in any direction, as well in a perpendicular, or in a diagonal, as horizontally and parallel to the site of the strata. For this reason they have obtained the name of *free-stone*. This stone is very soft when it comes out of the quarry, works very easily, but becomes in time very hard and durable.

POSITION, in architecture, the situation of a building with regard to the points of the horizon. Vitruvius directs the position of a building to be such, that the four corners may point directly to the four winds.

Position, in geometry, a term sometimes used in contradistinction to *magnitude*. Thus a line is said to be *given in position* (*positione data*) when its situation, bearing, or direction, with regard to some other line, is given: on the contrary, a line is *given in magnitude*, when its length is given, but not its situation.

Sir Isaac Newton shows how to find a point, from which three lines, perpendicularly let fall, to three other lines given in position, have any given ratio, &c.

POST, in building, a large piece of timber, placed upright in houses, &c. The corner posts are called the *principal*, or *fencing* posts; the posts framed between the principal posts for strengthening the roof of a house are called the *queen-posts*. An excellent method to preserve posts from rotting, is to burn the outside of the ends that are to be set in the ground to a coal.

Post, *Crown*, or King-Post. *See* Crown-Post.

Post and Paling, a kind of close wooden fence, constructed by means of posts set into the ground, and pales nailed to rails between them.

This sort of fence can seldom be had recourse to for common farm-purposes, except about the buildings or home-stalls. The only circumstances concerning it, which seem to require any notice in this place, are, that the posts, whether of rough or sawn timber, should be charred, or burnt, in a superficial manner, in the parts which are designed to be set in, or nearly on a level with the surface of the ground, in order to prevent their decay in these places. The posts should also be well and firmly put into the earth; and the sawn rails, whether for close or open paling, should be cut triangularwise, by slitting square scantlings diagonally. The pales of open paling should be cut in the same manner; the broadest sides of the pales being firmly nailed against the broad flat sides of the rails, at such distances from each other, and of such height and strength, as the given purpose may stand in need of, or require.

Post and Railing, another sort of open wooden fence, often used for protecting young quick-hedges, consisting of posts and rails, &c.

These sorts of fences, or protections, should likewise have constantly the parts which are set into the ground, and the rails, prepared in the same manner as directed above.

POSTERN, a small doorway in the rear of a building, more particularly applied to those of castles, which were reserved for private communication with the exterior.

POSTICUM, the postern-gate, or back-door, of any fabric, for private entrance.

POSTIQUE (from the Italian *posticcio*, *ad-led*;) an ornament of sculpture is said to be *postique*, when it is superadded after the work itself is done. A table of marble, or other matter, is also said to be *postique*, when it is incrustated in a decoration of architecture, &c.

POSTSCENIUM, or Parascenium, among the Romans, was a place behind the theatre, where the actors withdrew to dress, undress, &c.

POT-METAL, that kind of stained glass into which the colours are incorporated while in a state of fusion.

POWDERINGS, a term sometimes used for devices serving to fill up vacant spaces in carved works; as also in escutcheons, writings, &c.

POWER, in mechanics, a force, which, being applied to a machine, tends to produce motion; whether it actually produces it or not. In the former case, it is called a *moving* power; in the latter, a *sustaining* power. If the power be a man, or a brute, it is called an *animate* power; if the air, water, fire, gravity, or elasticity, an *inanimate* power. *See* FORCE.

POWER, is also used for any of the six simple machines, viz., the *lever*, *balance*, *screw*, *axis in peritrochio*, *wedge*, and *pulley*; which are particularly called the *mechanical powers*.

POZZOLANA. *See* PUZZOLANA.

PRACTICE. See CROSS MULTIPLICATION.

PRAXITELES, a celebrated sculptor of antiquity, born in Magna Græcia, who flourished about the year 364 B. C. He excelled particularly in the working of marble, and was the author of some of the most famous statues noticed by ancient writers; among these were two of Venus, one clothed and the other naked. The first was purchased by the Coans, who preferred it as the most decent. The Cnidians took the other, which was so exquisitely beautiful, that many persons took a voyage to the island for the sole purpose of seeing it. Praxiteles was deeply enamoured of the famous courtezan Phryne, of whom he made several statues, one of which was erected at Delphi. Many of his performances were in the Ceramicus at Athens; among the rest the statues of Harmodius and Aristogiton, which Xerxes carried away, and Alexander afterwards restored. Many were extant at a later period in Rome. His most noted works were in marble, but he cast many statues in metal, which, as well as those of marble, were greatly admired. He had a son, Cephissodorus, who inherited his skill and fame.

PREACHING CROSS, a cross erected in the highway for the purpose of preaching, as implied by the adjective.

PRECEPTORY, a subordinate or branch establishment of Knights' Templars, under the management of a *preceptor*; the same as the *commandery* of the Knights' Hospitallers.

PREPARATION, (from the Latin, *præparatio*), in mathematics, one of the parts or branches of a demonstration.

If it be a proposition in geometry that is to be demonstrated, the preparation consists in certain lines to be drawn in the figure: if a proposition in arithmetic, in some computation to be made, to obtain more easily the demonstration.

PRESBYTERY, that part of the church in the chancel set apart for the officiating priests.

PRESERVING OF TIMBER. *See* TIMBER.

PRICE BOOK, a book containing the prices of labour and materials, of the various articles employed in building. See *The Universal Price Book*, with regard to labour only, under the articles Carpentry and Joinery.

PRICK-POST, or QUEEN-POST. *See* Post.

PRIME FIGURE, in geometry, one that cannot be divided into any other figures more simple than itself.

Such is a triangle among planes; and the pyramids in solids. For all planes are made of the first, and all bodies, or solids, are compounded of the second.

PRIMING, among painters, the laying on of the first colour.

PRINCIPAL BRACE, a brace immediately under the principal rafters or parallel to them, in a state of compression, assisting with the principals to support the timbers of the roof.

PRINCIPAL POINT, a point in the perspective plane, upon which a line drawn from the eye, perpendicular to the plane, falls. This point is in the intersection of the horizontal and vertical plane; and is also called the *point of sight*, and *point of the eye*. *See* PERSPECTIVE.

PRINCIPAL RAFTERS, two inclined timbers in a roof, either meeting each other in the middle, or the ends of a beam in the middle of the roof, the lower ends resting on the ends of the tie-beam: their office is to support the roof.

PRINCIPAL RAY, that which passes perpendicularly from the spectator's eye to the perspective plane, or picture. Whence the point where this ray falls on the plane is, by some, called *the principal point*, which other writers call *the centre of the picture*, and *the point of concurrence*.

PRIORY denotes a society of religious, the superior of which was denominated a prior, or prioress; and of these there were two sorts; as where the prior was chief governor, as fully as any abbot in his abbey, and was chosen by the convent; such were the cathedral priors, and most of the Austin order, and where the priory was a cell subordinate to some great abbey, and the prior was placed and displaced at the will of the abbot.

PRISM, (from *πρίσμα*, something sawn, or cut off) in geometry, an oblong, or solid body, contained under more than four planes, and whose bases are equal, parallel, and alike situate.

PRISMOID, (formed of *πρίσμα* and *εἶδος*) a solid figure, having for its two ends any dissimilar parallel plane figures of the same number of sides, and all the upright sides of the solid trapezoids. If the ends of the prismoid be bounded by dissimilar curves, it is sometimes called a *cylindroid*.

To find the solidity of a prismoid, the general rule is: To the sum of the areas of the two ends, add four times the area of a section parallel to, and equally distant from both ends: multiply the last sum by the height, and one-sixth of the product will be the solidity. Or, if the basis be dissimilar rectangles, take two corresponding dimensions, and multiply each by the sum of double the other dimension of the same end, and the dimension of the other end corresponding to this last dimension: then multiply the sum of the products by the height, and one-sixth of the last product will be the solidity.

PRISON, an edifice erected for the confinement of debtors and criminals, until they be discharged or convicted. The principal properties in the construction of a prison, are those of strength and convenience. Strength is of the utmost consequence, in order to prevent the escape of the prisoners; and convenience, to promote their health; to have the apartments of their due size and arrangement, according to the different species of criminals, and to be handy in respect of the keeper.

Before the philanthropic labours of the celebrated Howard had made known to the world the dreadful condition of the public prisons of that day, such places were hardly fitted for the habitations even of the lowest animals, much less for the confinement of human beings. But his exertions having called public attention to the subject, a gradual amelioration has taken place, not only in the construction but in the whole system of prison discipline; until it may be doubted whether modern philanthropy is not running into the opposite extreme, and rendering abodes intended for the punishment of the vicious, superior to those attainable by the unfortunate and the poor.

It would be impossible to point out with any degree of minuteness the successive steps in prison improvement; nor is it, perhaps, strictly within the objects of this work to do so; it will be sufficient to describe one or two modern

buildings adapted for the confinement of criminals, as specimens of the great advance made within the last few years.

Before doing so, however, it may not be uninteresting to give Mr. Howard's recommendations relative to the situation and arrangements of a prison, by way of showing the ideas entertained at that time on the subject.

"A county gaol," he says, "and indeed every prison, should be built on a spot that is airy, and, if possible, near a river, or brook. I have commonly found prisons situate near a river, the cleanest and most healthy. They generally have not (and, indeed, could not well have) subterraneous dungeons, which have been so fatal to thousands: and, by their nearness to running water, another evil, almost as noxious, is prevented, that is, the stench of sewers.

"I said, a gaol should be near a stream; but I must annex this caution, that it be not so near as that either the house or yard shall be within the reach of floods. This was so little thought of at Appleby, in Westmoreland, when their new gaol was first building, that I saw the walls marked from nine inches to three feet high by floods.

"If it be not practicable to build near a stream, then an eminence should be chosen: for as the wall round a prison should be so high as greatly to obstruct a free circulation of air, this inconvenience should be lessened by rising ground, and the prison should not be surrounded by other buildings, nor built in the middle of a town or city.

"That part of the building which is detached from the walls, and contains the men-felons' ward, may be square, or rectangular, raised on arcades, that it may be more airy, and leave under it a dry walk in wet weather. These wards over arcades are also best for safety; for I have found that escapes have been most commonly effected by undermining cells and dungeons. If felons should find any other means to break out of this raised ward, they will still be stopped by the wall of the court, which is the principal security; and the walls of the wards need not then be of that great thickness they are generally built, whereby the access of light and air is impeded.

"I wish to have so many small rooms, or cabins, that each criminal may sleep alone. These rooms to be ten feet high to the crown of the arch, and have double doors, one of them iron-latticed, for the circulation of air. If it be difficult to prevent their being together in the day-time, they should, by all means, be separated at night. Solitude and silence are favourable to reflection; and may, possibly, lead them to repentance. Privacy and hours of thoughtfulness are necessary for those who must soon leave the world; (yet how contrary to this is our practice! Keepers have assured me, that they have made £5 a day after the condemnation of their prisoners.)—In the Old Newgate there were fifteen cells for persons in this situation, which are still left standing, and are annexed to the new building.

"The separation I am pleading for, especially at night, would prevent escapes, or make them very difficult; for that is the time in which they are generally planned, and effected. This also would prevent their robbing one another in the night. Another reason for separation is, that it would free gaolers from a difficulty of which I have heard them complain: they hardly know where to keep criminals admitted to be evidence for the king: these would be murdered by their accomplices, if put among them; and in more than one prison, I have seen them, for that reason, put in the women's ward.

"Where there are opposite windows, they should have shutters; but these should be open all day. In the men-felons' ward, the windows should be six feet from the floor; there should be no glass; nor should the prisoners be allowed to stop them with straw, &c.

"The women-felons' ward should be quite distinct from that of the men; and the young criminals from old and hardened offenders. Each of these three classes should also have their day-room, or kitchen, with a fire-place; and their court and offices all separate.

"Every court should be paved with flags, or flat stones, for the more convenient washing it; and have a good pump, or water laid on—both, if possible; and the pump and pipes should be repaired as soon as they need it; otherwise the gaols will soon be offensive and unwholesome, as I have always found them to be in such cases. A small stream constantly running in the court is very desirable. In a room, or shed, near the pump, or pipe, there should be a commodious bath, with steps (as there is in some country hospitals) to wash prisoners that come in dirty, and to induce them afterwards to the frequent use of it. It should be filled every morning, and let off in the evening through the sewers into the drains. There should also be a copper in the shed, to heat a quantity of water sufficient to warm that in the bath, for those that are sickly. There should also be an oven: nothing so effectually destroys vermin in clothes and bedding, nor purifies them so thoroughly when tainted with infection, as being a few hours in an oven moderately heated.

"The infirmary, or sick wards, should be in the most airy part of the court, quite detached from the rest of the gaol, and raised on arcades. These rooms should never be without crib beds and bedding. In the middle of the floor of each room there should be a grate of twelve or fourteen inches square, for a current of air, covered with a shutter or hatch at night.

"The sewers, or vaults, of all prisons, should be in the courts, and not in the passages, and (like those in the colleges) close boarded between the seat up to the ceiling, the boards projecting ten inches before each seat.

"The infirmary and sheds will not render the court unsafe, provided the walls have parapets, or small *chevaux de frise.*

"Debtors and felons should have wards totally separate; the peace, the cleanliness, the health, and morals of debtors, cannot be secured otherwise.

"The ward for men-debtors should also be over arcades, and placed on one side of the gaoler's house. This house should be in or near the middle of the gaol, with windows to the felons' and the debtors' courts. This would be a check on the prisoners, to keep them in order; and would engage the gaoler to be attentive to cleanliness and constant washing, to prevent his own apartments from being offensive.

"A chapel is necessary in a gaol. I have chosen for it what seems to me a proper situation. It should have a gallery for debtors, or women; for the latter should be out of sight of all the other prisoners, and the rest may be separated below. Bibles and prayer-books should be chained at convenient distances on each side: those who tear, or otherwise damage them, should be punished."

The introduction of the separate system of confining prisoners, led to great alterations in the mode of constructing prisons; and the penitentiary at Millbank was built for the purpose of carrying this plan of prison-discipline into effect. It was completed in the year 1821, and is calculated for the reception of twelve hundred convicts. The outer walls inclosed not less than eighteen acres. The principal entrance on Millbank is a stone-fronted lodge, with a Gothic arch, and false portcullis over the gates. At the top, "Penitentiary" is written in large characters. The cells for solitary confinement are arranged within the quadrangular building, which stands a considerable distance from the outer wall. At each

angle of the structure there is a tower or bastion to form water-closets, to communicate with the different ranges of cells. Each side has three tiers of windows (twenty-seven in a tier) strongly grated with iron. The bastions are also pierced for loop-holes, to give light and air. Projections, or out-works, are built for various departments, and the space between the building and the wall is laid out as gardens.

The model prison at Pentonville was planned with a view to embrace every improvement that modern science could suggest. It is placed in an elevated and airy situation, well adapted for such a building, and for securing the health of the prisoners. The following description will show the general principle adopted in its construction.

The boundary-wall is of a height above the ground sufficient to preclude all chance of escape by climbing, and the foundation of such a depth as to prevent undermining in the course of a single night. It presents an even, smooth surface on both sides. A clear space is preserved on the outside of the boundary, that no erection may be made against it, and that the exterior may be open to inspection; and in like manner the prison-wings are not connected with it, but a clear space preserved round the interior. There is only one gateway in this external boundary, which is placed immediately opposite the entrance-door, opening into an enclosed court-yard. The gate being retired a little, it is deemed will be of advantage in affording the means of defending it through loop-holes made in the side-walls, should attempts be made to force it during riots or popular excitement. Accommodation is afforded within the prison walls for officers, in detached houses. The prison is entered by a broad passage, leading through the entrance-building to the central hall, on the sides of which are convenient apartments for turnkey, male and female superintendents, and surgeon, and a mess-room for the officers, together with a room for the magistrates, and an office for the governor. These last rooms look into a central-hall, and command a view of the interior of the prison; there are likewise staircases leading to the basement, infirmary, and chapel. The basement of the entrance-building contains reception-cells, a cleansing-room for males, a fumigating oven for disinfecting prisoners, clothes; store-rooms for clothing; and prison stores, such as bedding, &c.; water-closet; and a room for the steward or prison-officer employed about the kitchen and store departments. A portion of the upper part of this entrance-building is appropriated as a chapel, and the remainder as an infirmary, or convalescent-rooms—the former entering into the central hall, and the latter entirely detached from the rest of the prison by a partition-wall, being a separate staircase from the passage below. The central hall, as before explained, opens from the floor to the roof, and is used as the principal station of the officers engaged in carrying on the discipline of the prison. A gallery—which is a continuation of that into which the prison-rooms or cells open—runs round the central hall, about ten feet above the floor, affording access to the chapel and all the wings, staircases being placed in convenient situations communicating with it. The windows of the hall overlook the airing-yards, and the greater part of the space within the boundary wall. The general kitchen of the prison, the bread-room, scullery, coal-cellar, and an apparatus for cooking, and for ventilating and warming the entrance-building, are situated in the basement under the central hall, and a small portion of the adjacent wings. The prison-wings, as before explained, radiate from the central hall, an open passage or corridor being designed to run longitudinally through the centre of each; and the prison-rooms, or cells, open into the corridor; these being ranged in three stories. The lower range is on the level of the floor of the corridor and hall; the upper ranges open upon a narrow gallery attached to the wall, which is continued round the central hall, as already explained. At the farther extremity of each prison-wing, a flight of steps, covered by a trap-door, lead to the punishment cells, which are placed in the basement. In the centre of each wing, a circular iron staircase is designed to communicate with the galleries, and continued into the store-rooms below. In addition to the stores and ventilating apparatus, placed in the basement, under the centre of each prison-wing is a large bath, the use of which is essentially conducive to the health of the prisoners. The general dimensions of the cells are about 13 feet long by 7 broad; 9 or 10 feet high to the under side of the arched ceiling. It is deemed desirable that the length should greatly exceed the breadth, as this affords a better opportunity of taking exercise, and facilitates the unobserved inspection of the interior. The partitions between the cells are not less than 18 inches in thickness, thereby precluding, as much as possible the transmission of sound between adjoining cells. The external walls are two bricks and a half thick, or two feet of stone; the internal walls next the corridor or passage, two bricks thick, or 18 inches of stone; the flues are 12 by 5 inches, and are worked in the corridor-wall and the external wall for ventilation. The windows of the cells are placed close under the arch, and have stone sills. The iron window-frame is a fixture let into a groove, with proper rebates for the glass, which is unpolished. The general dimensions of the windows are about 3 feet 6 inches long, and not exceeding 11 inches in breadth. For additional security, a strong wrought-iron bar is placed outside the window-frame, in the direction of its length, so as to divide the opening into two portions of about 5 inches each. The cells have single doors, the frame of which is of oak, 6 inches by 5; the doors, 2 inches thick, of deal, framed flush on both sides; the edges covered with felt, to prevent noise in the transmission of sound; a strong iron plating is on the side next the cell, riveted through, and the doors are hung with strong 4½-inch butt hinges, and fastened with a spring lock and latch; a bevelled aperture is cut for the inspection slide; and a trap-door, 6 by 9, is fixed in the door for passing provisions through, and which is hung on two centres, so as to form a shelf when let down; it is fitted with a strong bottom thumb-bolt, to secure it in its place. The outer door next the corridor is hung with 4½-inch butt hinges, working on centres, the object being that the door may be opened without noise, for inspection; the edge is covered with felt, and shuts into a rebate in the door frame, flush with the wall. For every cell there are suitable means provided for a constant supply of fresh water, and for necessary relief, without entailing unwholesome smells. The exercise of prisoners in the open air, without compromising individual separation, is thus obtained. The airing-yards radiate from a central point, round which is placed a dark passage, affording an inspection into each yard. The advantage of a dark passage is, that it facilitates close and unobserved inspection. The yards have open railings at both extremities, in order to allow a free circulation of air; and they are so constructed that no two prisoners can see each other. A small roof is attached to the division-walls, to afford shelter when necessary: and the position of the yards with reference to the doors in the centre of the prison-wings, gives a ready means of access from the cells.

The chapel is fitted up with separate stalls or sittings; the sides of each stall, and the doors, which form the continuation of those sides, and shut up the general passage to each row, radiate upon the pulpit, so that each prisoner can see, and be seen, by the chaplain. The back of each row of seats is made

of such a height as to intercept the communication between the rows, when the prisoners are standing up, and yet not so high as to conceal them from the observation of the prison-officers when sitting down. A double passage is made down the centre of the chapel, opening into and communicating with the gallery surrounding the central hall, and thus affording two points of access to it. A staircase leads from the gallery to a door on a convenient level for entering, near the upper row of seats, from whence a succession of steps, arranged in pairs, communicate downwards with each row in front. The ceiling of the chapel is coved, and ventilators are introduced into it; the roof and the bearers supporting the seats being made of iron. For the ventilation of the cells, an apparatus is placed in the centre of the basement-story of each wing, the object of which is to secure a more complete ventilation than could be obtained, if the system had been extended from either extremity. The apparatus consists of a proportion of large tubes or pipes for hot water, and in connection with it there is a large cold-air flue communicating with a shaft out of doors, which serves for two wings. The fresh air introduced through the flue, is brought in contact with and passes through the tubes of the apparatus, and may therefore be warmed or left at its natural temperature, as may be desirable. The air thus brought from without, then passes to the right and left along the flue which runs horizontally under the floor of the corridor, from whence a communication is established by lateral small flues, separately with each cell, both on the lower and upper floors.

The means whereby foul air is extracted from the flues are these: a grating is placed close to the door of each cell, on the side next to the outer wall, and diagonally opposite to where the fresh air is introduced. This grate opens into a flue which passes down the outer wall, and communicates with a main foul-air flue placed under the floor of the basement. These main foul-air flues terminate in a chimney-shaft rising above the top of the building. With a view to obstruct the transmission of sound, and prevent that communication which might be attempted by means of the flues, the main foul-air flues are divided into three compartments, one for each range of cells. By means of the system of flues which has been described, a communication is established—first, from the outer-air, and then from the floor of each cell back again through the extracting or foul-air flues or chimney into the outer air. In order to regulate the quantity of air admitted into each cell, which, with apertures of equal size, would differ in proportion to the distance from the apparatus, a valve or damper may be placed in the extracting flues, close to the outer door of each cell in the corridor, so constructed as not to close it up entirely, but to leave sufficient range to operate upon the circulation; the damper being at the command of the superintending officer, he is enabled to regulate the quantity according to circumstances. By the application of this system of ventilation, it has been found that a circulation of air of from six to eight cubic feet per minute, may be kept up through all the cells, at all times of the year, and under all possible circumstances, when the doors and windows of each are perfectly closed.—*Fourth Report of the Inspectors of Prisons.*

In September, 1847, a number of gentlemen taking an active part in the management of prisons, assembled at Brussels under the title of a "Penitentiary Congress;" for the purpose of discussing various questions connected with prison discipline. In this "Congress," colonel Jebb commissioned by the secretary of state (for England), Mr. B. Rotch (the Middlesex magistrate), and Mr. Charles Pearson, took a distinguished part.

"Foremost amongst the subjects of debate was *the mode of constructing cellular prisons*; and, as this is a matter which greatly concerns architects and others of our readers, we deem it right to record the results.

"Colonel Jebb rightly remarked, that there was an intimate connection between the construction and the discipline of a prison. He was impressed with the necessity of having the various departments and the various offices of the establishment kept quite distinct one from the other, with a convenient mode of access to the centre and the cells. It was also essential that the families of the officers should not live in the prisons; that the latter should come to their employment at a certain hour during the day, and attend alternately at night. He saw by a paragraph in the programme, that it was proposed not to construct prisons with more than three stories, including the ground-floor. He thought, however, when the number of prisoners amounted to 700 or 800, it would be more convenient to have four stories, than very long wings. With respect to the attending of divine worship, a mode existed in Pentonville and other places, by which all the prisoners might proceed separately to the church or chapel, and hear and see the person officiating, without being seen by any one, except by him. The time occupied in proceeding to and departing from divine service, was seven minutes respectively. With respect to the size of the cells, he thought that, as a general rule, they should be about 13 feet long, 7 broad, and from 8 to 9 feet high. Of course it would be necessary sometimes to make larger cells for special purposes."

The following are some of the propositions, which were agreed to *nem. con.*

"The buildings and exercise-ground should be disposed so as to receive the rays of the sun, and be sheltered from rain and the north wind. 2nd. The destination of a prison must in some sort determine its internal arrangement. If it is to be a penal prison, none but convicts of one sex should be placed in each, and the number should never surpass the maximum of 500, although the congress were of opinion that a less number would be better. If it is to be a preventive establishment, different wings and sections should be parted off for the different categories of prisoners. The two sexes at any rate must be kept distinct. 3rd. The number of stories should not be more than three, including the ground-floor. The parts of the prison specially destined for persons undergoing their sentences, should be disposed in such a manner as, 1st, to allow of a complete separation by day as well as by night; 2nd, to give them the means of open-air exercise; 3rd, to enable them to be suitably employed, to receive instruction, and to assist at divine service and religious exercises, without infringing the rule of separation. 4th. To facilitate the mode of superintendence of the prisoners, and of frequent communication with them."

The following propositions were read and discussed:—

"*Central Observatory.*—The various parts of the building should be connected with a central point of inspection, from which the head of the establishment may inspect, without being under the necessity of moving all the essential branches of the service. Regard must be had to the internal distribution of the localities, to the arrangement of the galleries, and to the choice of the materials of construction, in order that no material obstacle may thwart that inspection.

"*Cells.*—In the disposition and arrangement of the cells, regard must be had to the following conditions:—1. The cells must be large enough to allow of the prisoners taking exercise, carrying on trades, and enjoying sufficient space and air for the preservation of their health: the space should vary from 28 to 35 cubic metres. 2. They should be

lighted up, ventilated, and heated in a suitable manner. 3. Their construction should be such as to allow no communication between their inmates. 4. They should be furnished with bed and bedding, with a fixed wash-hand basin with a tap; with a water-closet, and with other necessary articles. The prisoners should also have the means of giving the alarm to the attendants, in case of illness or accident, or under any circumstances in which their presence might be necessary. The prisoners should be subjected to an easy, but unperceived inspection.

"*Special Cells.*—In penal prisons, it is necessary to have a certain number of special cells for the infirmary, for special punishments, for the different callings, and for prisoners on their first arrival. The cells for infirmaries, chiefly reserved for patients who cannot be suitably attended to in the ordinary cells, should be more spacious than the former, and should be disposed in such a manner as to allow of the access of the attendants. One cell of that kind for every forty or fifty prisoners would possibly be sufficient. Cells for punishment should be stronger than others, and should be built in such a manner as to be easily darkened, if necessary. One such cell would be sufficient for about 100 prisoners. The dimensions of the cells for the exercise of certain trades should correspond with the use to which they are put: they should be situated in preference on the lower stories, and their number must depend on the nature of the trades carried on in the prison. In prisons where prisoners are constantly arriving, a certain number of cells should be made, in which each prisoner may be placed temporarily, previous to being seen by the surgeon: and such cells might be of smaller dimensions than others.

"*Heating and Ventilation.*—Whatever the system of ventilating by heating may be, its result should be the following:—A sufficiency to each cell of fresh air, or, if necessary, of air tempered for each prisoner, without the inconvenience of draughts. The extraction from each cell of a quantity of foul air equivalent to the quantity of pure air introduced, and of the carrying on of the heating and ventilating without facilitating the means of communication, whether of sound or otherwise, between the different cells.

"Mr. Rotch said, that excellent as the Pentonville prison was, he could not help saying that many things were wanting to render that establishment perfect. All the medical men to whom he had spoken on the subject were of opinion, that the temperature should be lowered at night-time. The mode of ventilation was not good in Pentonville: and he would just observe, that if people were satisfied with what was simply good, they would never have better. The question of ventilation was a most important one, particularly for nations which, unlike England, had no colonies to which criminals might be transported, and which were, therefore, under the necessity of detaining the criminals for a long time in prison. It must not be said that there was no way of bringing the fresh air into prisons conducted on the cellular system; but rather urge architects *to find out a plan to that effect before the next congress was held.* The system of ventilation in Clerkenwell prison had been lately changed, because it was found to be a bad one. Mr. Rotch here showed the meeting a plan for procuring ventilation: the principle appearing to be, that fresh air should be applied from the lower parts of the building, whilst the foul air should escape from the roof of the house. He would just state one fact, to show that at Pentonville some improvements were required. About three weeks ago, he had been informed by one of the furnace or oven men of that prison, that it required thirty-six hours to lower the temperature.

"Colonel Jebb admitted that it would be better to admit air into the prison by means of open windows; but then such windows would admit of communication between the cells. He did not think that the present system at Pentonville could be well changed at present, without endangering the health of the inmates. Should the medical men, however, decide otherwise, alterations would be made. He thought that the present mode of ventilation would not act prejudicially on the health of the inmates during the eighteen months or so they remained in the model prison.

"The article in favour of the establishment of a central observatory of inspection was adopted; as was also one relating to cells, with the exception of a sentence which fixed their space at from 28 to 35 cubic metres."

The congress also adopted the following propositions:—

"*Chapels.*—The chapel should be so disposed as that each prisoner should join in the exercise of worship—seeing and hearing the minister officiate, without being himself seen; regard being had, at the same time, to the fundamental principle of the separation of prisoners amongst themselves.

"*Parlours.*—A certain number of cell-parlours should be made, for the use of prisoners not authorized to meet their relations or friends in their own cells.

"*Domestic Service—Administration—Lodging of persons employed in Prisons.*—Whatever plan may be adopted, independent of the localities above mentioned, each prison on the cellular system should contain a bath-room, with a number of separate baths in proportion to the number of inmates; a kitchen, with its accessories; a baking-house; and a wash-house: a certain number of magazines for provisions, fuel, clothes, general stores, and manufactured goods, according to the destination of the prison; a clerk's office; and a meeting-room for the committee of surveillance; lodgings for the director or chief officer, the guards, or watchers; and, in penal prisons, for the sub-director, the superintendent of works, the almoner, the doctor or his assistant, and of such other persons as may be placed in each prison by the administration."—*Builder October* 9, 1847.

In the new prison which has been built at Holloway, for the Corporation of London, it has been endeavoured to carry out these ideas. It is constructed upon the radiating principle, having four wings diverging from one centre, with two other wings in front of the former: one of these wings is for juvenile offenders, with school-rooms attached; the other for females, with work-rooms and laundry; the other four radiating wings constitute the male adult prison. These have large work-rooms attached, and an apparatus for lifting water. The wings are twelve cells in length, or about 100 feet, and 3 stories high. The corridors are 16 feet wide, and are open up to the arched ceiling, with galleries leading to the upper cells. The cells are 13 feet by 7 feet, fitted up with water-closets, wash-hand basin, cupboard, table, stool, &c: these are warmed by means of hot-water pipes laid under the corridor-floor, the air passing over them and through the flues provided in the thickness of the wall, and entering the cell over the door. The ventilation is to be effected by means of a shaft, 146 feet high, of large dimensions. Inside this shaft is a tube of boiler-plate the whole height of the shaft, 5 feet diameter at bottom and 3 feet at top. In addition to a furnace at the bottom of the tube, the smoke from the various chimneys, together with the spare heat from the kitchen boilers, is conveyed into it, and will necessarily raise the temperature of the column of air in the shaft, and make it pass off with great rapidity. The theory is, that as no air can enter the shaft without previously passing through the cell, a constant supply of fresh air will thereby be conveyed to the prisoners.

The chapel is a spacious room 70 feet by 40, and 48 feet

to the ridge of the roof, with two deep recesses for the females and juveniles, and will contain sittings for 380 prisoners. Provision is made for having a constant supply of fresh air passing through the chapel to the ventilating shaft. The arrangements for taking the prisoners from the various cells to the chapel, have been well considered. The females and juveniles enter by separate doors near the altar, while the male prisoners enter by four different passages at the opposite end. The kitchen is of ample dimensions, and being close to the base of the ventilating shaft, the steam and smell from the victuals will be readily carried off. The well-house is to be fitted with one of Mr. Bessemer's disc pumps, and to be worked like a capstan, in a building 30 feet diameter. The shaft is 217 feet deep, bore 102 feet, making a total depth of 319 feet. The depth to the water is 153 feet. The tanks, to contain 14,000 gallons, are placed over the front towers at a great elevation, from which the cells and other places are supplied: the whole depth of bore is in chalk.

The whole extent of frontage next the Camden-road is of Kentish rag, with Caen-stone dressings. The style is castellated Gothic. The sides of the chapel building, and the back wings, are of brick; the windows to the cells have Parkspring-stone sills, with splayed brick reveals. The whole of the parapets are coped with Caen-stone. The roofs are flat, covered with asphalte, upon plain tiles and iron rafters. As the extracting flues for ventilation are immediately under the roof-covering, two thicknesses of plain tiles have been put 6 inches apart, to prevent the atmosphere acting in any way against the free current of air passing through them.

The porter's lodge, which stands about 66 feet in front of the entrance-building, is also of rag, with Caen-stone dressings, and contains accommodation for two families. Between the last-named building and the road, stand the two houses intended for the governor and chaplain, with large gardens attached.

The accommodation afforded in the prison is as follows—

Females	60	
Juveniles	61	
Male adults	283	
		404
Reception cells	14	
Punishment ditto	18	
		436

with fourteen work-rooms, equal to ninety-six cells; offices for the governor, chaplain, surgeon, steward, clerks, &c.; apartments for the surgeon and deputy-governor, and for master and two turnkeys in juvenile wing, matron and two turnkeys in female wing. The ground, consisting of ten acres, is surrounded by a brick wall 18 feet high with a strip of land 20 feet broad round its exterior.

The prison is built upon land originally purchased by the City for the purposes of a cemetery during the raging of the cholera in 1832. It is a little to the westward of the Holloway-road, upon the side of a hill, having a declivity of 4 feet in 100. Previous to the commencement of the works, the City authorities entered into an arrangement with the commissioners of sewers, who built a new sewer for the purpose of securing good drainage for the prison.

The building has been erected from the design and under the able superintendence of Mr. Bunning, the City architect. Mr. Jay is the contractor employed; Mr Lawrie, the clerk of the works.

The original estimate for the building was £92,293; but the committee considered that sum too large, and orders were given to cut it down. The pruning knife was applied, and it was reduced to the extent of £14,635. The contract now stands as follows:—Buildings, £77,655; warming, ventilating, water-pipes, gas fittings, locks, bells, cooking apparatus, laundry fittings, forming the grounds, fittings and furniture, about £14,000; so that, after allowing for any additions the corporation may think proper to make, the expense of the whole may be called something under £100,000.

Prison-discipline is a problem the wisest of our legislators have not been able to solve. When Pentonville prison was erected, it was thought that complete separation, by its severity, would lessen crime. The result, however, has scarcely justified the belief. The government have had ample opportunity of forming an opinion upon the merits of the separate system; consequently, within the last twelve months, some relaxation has been made, and about 10 per cent, as we understand, are now in association.

With so many perplexing opinions before them, the City authorities were at a loss upon what principle to arrange their prison, but they adopted a middle course, and they have now the means of confining the vicious in separate cells; and have a sufficient number of work-rooms for classified association.

It is expected that this prison will be ready for occupation in the early part of the year 1852. *Builder*, 1851.

PROBLEM, (from *πρόβλημα*) in geometry, a proposition in which some operation, or construction, is required; as to divide a line, to make an angle,to draw a circle through three points not in a right line, &c.

Messieurs, of the Port Royal, define a *geometrical* problem, a proposition given to be demonstrated, in which something is required to be done; and what is done, to be proved to be the thing required.

A problem, according to Wolfius, consists of three parts: the proposition, which expresses what is to be done; the resolution or solution, wherein the several steps, by which the thing required is to be effected, are orderly rehearsed; the demonstration, in which is shown, that by doing the several things prescribed in the resolution, the thing required is obtained.

Accordingly, the general tenor of all problems is this: the things prescribed in the resolution being done, the thing required is done.

PRODUCING, in geometry, the continuing a right line, or drawing it out to any assigned length.

PROFILE, (French) in architecture, the figure or draught of a building, fortification, or the like; in which are expressed the several heights, widths, and thicknesses, such as they would appear, were the building cut down perpendicularly from the roof to the foundation. Hence the profile is also called the *section*, sometimes the *orthographical section;* and by Vitruvius, also the *sciagraphy*.

PROFILE in this sense, amounts to the same with *elevation;* and stands opposed to *a plan*, or ichnography.

PROFILE is also used for the contour, or outline of a figure, building, member of architecture, or the like; as a base, a cornice, &c.

Hence, *profiling* is sometimes used for designing, or describing the member with rule, compass, &c.

PROJECTION, the art of forming the representation of a body upon a plane, by drawing straight lines through a given point, or parallel from the contour, and from the intermediate lines of the body, if any, so as to cut the plane; then colouring the respective compartments according to the degree of light, shade, and line of each surface.

If the projection be made by drawing straight lines from a point, it is called *a perspective representation;* but if formed by parallel lines, it is called an *orthographical representation.*

The projections of points, lines, and plane figures, are found by placing the originals in a given original plane, in a certain position to the intersection of such plane with the plane of projection: and thence the projections of the faces of solids are easily discovered, either by finding the intersection of their planes with the plane of projection, or by finding the representation of one of the planes, and the representation of lines making any given angle with the original of the plane to be represented; and thus the seat, inclination, and length of the original line must be known. Each of these methods has its advantage: but that in which the representations are obtained, by finding the intersections of the different planes forming each of the solid angles, having the inclinations of their planes, is the most natural, as well as the most universal in its application; though the other method, where the objects to be represented are prisms, is more expeditious; since, if the representation of one of the ends be found, the whole solid may be also obtained by finding the representation of one of the arrises, or edges, of the planes which form the sides; or, in the case of a cylinder or cylindroid, by finding the representation of the axis, then drawing lines from all points of the base, or from a sufficient number of points in the base, parallel and equal in length to the axis, and completing the other end equal and similar to the one projected, will complete the representation of the whole solid.

Every solid, whose properties are known, may be projected in any given position to the plane of projection; and no other method offers such ready means of projecting points or lines in space, which have a relation to a given or original plane, where the original plane and the plane of projection are given in position.

In the doctrine of shadows, nothing can be more easy, or more convenient, than the methods furnished by this principle; the universality of the rules is such, that they apply equally to perspective and to orthographical representations, and are much more convenient than the method of finding the vanishing lines of their planes and those of the planes of shade.

Definition 1.—The plane on which the object is represented, is called *the plane of projection.*

In orthographical projection, the rays by which the projection is formed, are here understood to be perpendicular to the plane of projection.

Definition 2.—If the projection be made on a plane parallel to the horizon, or on a plane representing the horizon, it is called *the plane of the object.*

Definition 3.—If the projection be made on a plane perpendicular to the horizon, or on a plane representing a vertical plane, it is called *the elevation of the object.*

Definition 4.—The *plane of position of an inclined line and a plane*, is another plane passing along the line perpendicular to the plane.

Definition 5.—The *inclination of a line to a plane*, is the angle on the plane of position comprehended between the line and the plane.

Definition 6.—The plane on which any object is given, is called *the primary plane.*

Definition 7.—A *point on a plane* is said to be *given*, when its situation is known in respect of some given line, relatively to some fixed point in that plane.

Definition 8.—The *position of a line to a plane* is said to be *given*, when the seat of the line is given upon the plane, and when the angle which the line makes with its seat is known.

Definition 9.—In the representation of figures, in planes inclined to the plane of projection, the situation of the figure, in respect to the intersection of its plane with the plane of projection, is supposed to be known. The intersection is therefore given on the plane of projection, and the space on the one side is to be considered as *the original plane*, while that on the other is *the plane of projection.*

Axiom.—If any point, line, or plane, coincide with the plane of projection, that point, line, or plane, so coincident, is both the original and the projection of that point, line, or plane.

Proposition I.—The projection of a point is in a straight line drawn from the original point perpendicular to the intersection.

For, suppose a plane to pass through the original point, perpendicular to the primary plane and to the plane of projection, its intersection with each of them will be perpendicular to that of the primary plane and the plane of projection; but lines perpendicular to the same straight line, drawn from the same point, are in the same straight line, and therefore the projection of a point is in a straight line drawn from the original point perpendicular to the plane of projection.

Proposition II.—The orthography, or projection of a straight line, is also a straight line. Thus, let a plane pass through the original straight line perpendicular to, and intersecting the plane of projection; here, as the intersection of one plane with another is a straight line, the orthographic representation must be so likewise.

Proposition III.—All original parallel straight lines are represented by parallel straight lines; because the intersection of one plane with another is a straight line; and, when a plane cuts several parallel planes, the intersections of these planes with the cutting plane, are parallels.

Proposition IV.—The orthographical representation of a line parallel to the plane of projection, is a line equal and parallel to its original.

Proposition V.—The orthographical representation of a line parallel to the intersection, is a line equal and parallel to the original.

Proposition VI.—The orthographical representation of a plane figure parallel to the plane of projection, is a figure equal and similar to the original.

Proposition VII.—All planes perpendicular to the plane of projection, are described as straight lines.

Proposition VIII.—All straight lines in the primary plane perpendicular to the intersection, have their representations also perpendicular to the intersection.

Proposition IX.—Every straight line in a plane perpendicular to the plane of projection, is represented by the intersection, or a part of the intersection, of that plane.

Proposition X.—The intersecting point of every line in any original plane is that point in the intersecting line of the original plane, which is cut by producing the original line to the intersecting line of the plane.

Proposition XI.—If, through any point in the original plane, a plane be drawn perpendicular to the intersection, so as to meet, or intersect, the plane of projection, the representation of the point will be in the line of section where it is cut by a perpendicular to such line, in the plane perpendicular to the intersection.

Proposition XII.—If two points in the intersection of one plane with another be found, or known, the intersecting line of the first plane in the second, is the line which joins the two points.

Proposition XIII.—If the intersecting lines of two planes, inclined to each other, be given, or found, upon a third plane,

the point of concourse of the two intersecting lines will be a point in the intersection of the two first planes.

Proposition XIV.—If two points be given in the projection of a straight line, the whole line is given in position.

PROBLEM I.—*Given a point on a plane, inclined to the plane of projection, to find the orthography, or projection of the point.*

Plate I. *Figure* 1.—Let I N be the given intersection of the inclined plane; and let A be the given point thereon; draw A *a* perpendicular to the intersection, I N, cutting it in B; make *a* B C equal to the inclination of the original plane to the plane of projection; make B C equal to B A, and draw C *a* perpendicular to A *a*; then will *a* be the projection of the point A.

Demonstration.—Conceive the triangle *a* B C to be turned up on the base B *a*, perpendicular to the plane of projection; also conceive the original plane, with the point A, to be turned on the line I N, as a hinge; and the line B A will always be in a vertical plane, whose intersection is A *a*; and since B C is equal to B A, and B C is also in the same vertical plane when turned up, B A may be made to coincide with B C; therefore let B A coincide with B C; and, because B C is equal to B A, the point A will fall upon C: but, because C *a* is perpendicular to B *a*, and the plane *a* B C is by supposition perpendicular to the plane of projection, therefore *a* C is perpendicular to the plane of projection; consequently *a* is the projection of the point A.

Corollary.—Hence the projection of a line may be obtained by finding the projection of two points in that line, and then joining the two projected points.

PROBLEM II.—*To find the projection of a straight line in the original plane.*

Figure 2.—Let A B be the given straight line; produce A B to its intersecting point, C; by PROBLEM I. find *a*, the representation of A; join *a* C; draw B *b* perpendicular to I N, cutting *a* C at *b*; then *a b* is the projection of the line required.

PROBLEM III.—*To find the orthographical projection of an angle.*

Figures 3 and 4.—Let A B C be the given angle; find *b*, the projection of the point B; produce A B and C B to their intersecting points, D and B; join E *b* and D *b*, and produce them to *a* and *c*, if necessary, as in *Figure* 3 (*Figure* 4 does not require it); then *a b c* is the projection of the angle required.

PROBLEM IV.—*The indefinite projection of a straight line being given; to find the projection of any original point therein.*

Figure 2.—Let *a* C be the indefinite projection of A B, and let it be required to find the projection of the point B, in the original line A B. Draw B *b* perpendicular to I N, cutting *a* C in *b*; and *b* will be the projection of the point B.

PROBLEM V.—*To find the projection of a given triangle.*

Figure 5.—Let A B C be the triangle given; find the projection, *a b c*, of the angle A B C; by Problem III. and by Problem IV. find the points *a* and *c*, the projections of the points A and C; join *a c*, and *a b c* will be the projection required.

PROBLEM VI.—*To find the projection of a parallelogram.*

First, when the sides are obliquely situate.

Figure 6. Let A B C D be the given parallelogram; find *a b c*, the representation of the angle A B C (being any one of the three angles that is most convenient) by Problem III. and the representations *a* and *c*, of the points A and C, by Problem IV.: draw *a d* parallel to *b c*, and *c d* parallel to *b a*; and the parallelogram *a b c d* will be the representation of the original parallelogram A B C D.

2. When the parallelogram is a rectangle, with its sides parallel and perpendicular to the intersecting line.

Plate II. *Figure* 1.—Find the representation of the points C, D in one of the sides, C D perpendicular to the intersection, by Problem I.; draw *d a* and *c b* parallel to the intersection I N; draw B *a* parallel to D *d*, cutting *c b* at *b*; then the rectangle *a b c d* will be the representation of the rectangle A B C D, as required.

3. When two of the sides are parallel and two oblique.

Figure 2.—Find the representation *a*, of the point A, by Problem I.; produce the side A B to its intersecting point, E; join the intersecting point E and the point *a*; draw B *b* perpendicular to the intersecting line, cutting E *a* at *b*; draw *b c* parallel to I N; draw C *c* parallel to B *b*; draw *c d* parallel to *b a*, and *a d* parallel to *b c*; and the parallelogram, *a b c d*, will be the representation of the original parallelogram A B C D, as required.

Note. Both of these might have been included in one problem; they are thus particularized, in order to give the reader a clear view of the subject.

PROBLEM VII.—*To find the representation of a regular pentagon.*

Figure 3.—Find *a*, the representation of the point A, by Problem I.; produce A E and A B to their intersecting points, and join each of those points with the point *a*; find the projections, *b* and *e*, of the points B and E, by Problem IV.; produce the diagonals, A C and A D, to their intersecting points, and find the representations, *c* and *d*, of C and D, by Problem IV.; join *e d*; and *a b c d* will be the representation required.

PROBLEM VIII.—*Given the intersecting line, and the projection of one of the angles of a pentagon, and the projected length of one of the sides: to project the whole figure.*

Figure 4.—Let *b a e* be the projection of one of the angles of a pentagon, say the most remote; produce *a b* and *a e* to F and G, their intersecting points; then, upon F G, describe the segment, F A G, of a circle, to contain the angle of a pentagon, that is, $\frac{3}{5}$ of two right angles; draw *a* A perpendicular to F G, to cut the segment in A; join A F and A G: let *a b* be the projected side given; draw *b* B perpendicular to F G, cutting A F at B; upon A B describe the regular pentagon A B C D E; and project the other parts, *b c*, *c d*, *d e*, as in the preceding example.

PROBLEM IX.—*To find the projection of a circle.*

Plate III. *Figure* 1.—Draw the diameter B D parallel, and the diameter C E perpendicular to the intersecting line; find *a*, the projection of the point A; and draw the diameter, *b d*, parallel to the intersecting line; find *b*, the projection of the point B; join B E, and produce it to f; join *b* f, cutting *a* A at *e*; then, with half the major axis, *a b*, and half the minor axis, *a e*, describe the ellipsis, *b c d e*, the projection required.

PROBLEM X.—*To find the projection of the segment,* B C D E B, *of a circle.*

Figure 2.—Through the centre, A, draw the diameter, C F, parallel to I N; complete the semi-circumference, C D F; find the axis *a c* and *a d*, as in the last problem; produce the chord B E, to meet the intersecting line, I N, in f; find the representation of the point *g*; join f *g*, and produce it to *b*; then, with the semi-axis *a c* and *a d*, describe an ellipsis, or so much of it as may be necessary; and the part, *b c d e b*, will be the representation of the segment, B C D E B, as required.

PROBLEM XI.—*To find the projection of an ellipsis,* B C D E B; B D *and* C E *being the two axes cutting each other at* A.

Figure 3.—Find the representations, *b d* and *c e*, of the axes; then with the diameters, *b d* and *c e*, descr be the

ellipsis *b c d e*. This may be done as in Problem I., Method V. of the article ELLIPSIS (Vol. I., page 365), or by finding the two axes, as in Method I, (page 365), of the same article.

PROBLEM XII.—*Any two conjugate diameters,* B D *and* E C, *of an ellipsis, being given; to find the representation of the ellipsis.*

Figure 4.—Find the representations. *b d* and *e c*, of the diameters B D and E C; and *b d* and *e c* will also be conjugate diameters; then, by PROBLEM I., Method I., of the article ELLIPSIS (Vol. I., page 365), describe the ellipsis *b c d e b*, which will be the representation of B C D E B, as required.

PROBLEM XIII.—*To find the projection of any point in space, upon a plane given in position; and to determine the distance of the point from the plane.*

Figure 5.—Make choice of any three points, A, B, C, on the plane; measure the distance of the point in space from each of the points A, B, C, and the distance of the points A, B, C, from each other; then the projection may be found on paper, thus: let Q R be a scale, representing feet and inches; let A B be measured 1 foot 4½ inches, B C 1 foot 1½ inch, and C A 1 foot 2 inches; describe the triangle, A B C, according to these dimensions from the scale; let the distance of the point in space from A be 1 foot 4 inches; with the centre, A, and distance of 1 foot 4 inches, describe an arc at D; let the distance of the point in space from B be measured 1 foot 3 inches; then, with the centre, B, and distance of 1 foot 3 inches, describe an arc cutting the former at D, and join A D and B D; with the same distance, from B, describe an arc at E; let the distance of the point in space from C be measured 1 foot; then, with the centre C, and distance of 1 foot, describe an arc, cutting the former at E, and join B E and C E; draw D *p* perpendicular to A B, and E *p* perpendicular to B C; and *p* will be the projection of the point in space.

To find the altitude of the point in space.—Let D *p* cut A B at F; draw *p* H perpendicular to F *p*; with the centre F, and distance F D, describe an arc, cutting *p* H at H; and *p* H will be the height of the point required.

Problem XIV.—*Supposing a tetraedral, or three-sided solid angle to be placed with one of its sides upon the plane of projection, and one of the other two sides, and the two inclinations adjoining that side, with the intersection of that side, to be given; to find the projection of the given side; and the intersection of the remaining side, upon the plane of projection.*

This problem is the same as if one of the sides, and the two adjoining inclinations, of a tatraedral, were given; to find the projection of the given side on one of the others, and also to find the side of the solid on which the projection is made.

Figure 6.—Let A B C be the given side, and A B the edge which intersects or meets the plane of projection in I N; from any point, C in B C, draw C D perpendicular to I N, cutting I N at A; find B D, the projection of B C; that is, make D A L equal to the inclination of the given plane towards the plane of projection; make A L equal to A C; draw L D perpendicular to C D; join D B; and D B A will be the projection of A B C, as required.

To find the intersection of the other side, with the plane of projection.

In B C, take any point, G; and draw G F perpendicular to B C, cutting A B at F; draw F I perpendicular to B D, cutting B D at H; with the centre F, and distance, F G, describe an arc, cutting B D at K; join F K; make the angle, F K I, equal to the other inclination; join B I; and B I will be the intersection of the other side, as required.

PROBLEM XV.—*Given the representation, a, of a point, situate in a plane, whose original is given: to find the representation of a line from the original point, perpendicular to the original plane.*

Plate IV. *Figures* 1, 2.—Draw G K perpendicular to the intersecting line, and make G K L equal to the inclination of the plane to that of projection, if not already made; draw *a* L perpendicular to G K, and L M perpendicular to K L; make L M equal to the line; draw *a b* parallel to G K, and M *b* parallel to L *a*; then *a b* will be the projection required.

PROBLEM XVI.—*Given the representation, a, of the intersection of a line with the original plane, and the seat in, and inclination of, the line, to the original plane; to find the representation of the line.*

Figures 3, 4.—Draw G K perpendicular to I N; make the angle G K L equal to the inclination of the plane to that of projection, and produce K L to M, if necessary; draw A *a* perpendicular to I N, and C *b* parallel to A *a*; make K M equal to C d; draw M P perpendicular to K L: make M P equal to the tangent of the seat, A C, made radius; draw C *b* parallel to A *a*, and P *b* perpendicular to A *a*; then join *a b*, and *a b* will be the representation of the line required.

PROBLEM XVII.—*Given the representation, a b c d, of one side of a parallelopiped, with the inclination of the plane, and the other dimension perpendicular to the original of that plane; to find the representation of the whole solid, supposing the planes of the original solid at right angles to each other.*

Figure 5.—Find the representation, *a f*, of a line perpendicular to the original of the plane represented, by Problem XV., and complete the parallelograms *a f g d* and *a b e f*, which will form the representation of the whole solid.

PROBLEM XVIII.—*To find the inclination of two adjoining planes of the regular solids.*

Plate V. *Figures* 1, 2, 3, 5.—Draw the base, A B C, A B C D, or A B C D E of the pyramid which forms one of the solid angles; draw the triangle B G C, the development of one of the sides of the pyramid; draw G F perpendicular to B C; bisect the angle A B C, and let the bisecting line meet G F in F, their point of concourse; draw F H perpendicular to B F; from B, with the radius B G, describe an arc, cutting F H at H; draw F I perpendicular to B H, cutting B H at I; in F B make F L equal to F I; let F H and B C meet in M; also let F H and B A meet in K; join M L and K L; then will K L M be the angle of the planes as required.

As the sides of the tetraedron are equilateral triangles, and as three of the triangles form each solid angle, both the base of the pyramid, A B C, and the developed side, B G C, will be equilateral triangles in *Figure* 1.

In the construction for *Figure* 2, as the sides of the hexaedron are squares, and as each solid angle is formed by three of the right angles, the base of the pyramid will be an equilateral triangle, and the vertical angle of the developed side will be a right angle.

In the construction for the octaedron, *Figure* 3, as each side is an equilateral triangle, and as four of the angles of the triangle form the sides of the solid angle, the base of the pyramid will be a square, and the developed side will be an equilateral triangle.

In the construction for the dodecaedron, *Figure* 4, No. 2, as each solid angle is formed by three planes, and as each of the planes is a pentagon, the base of the pyramid will be an equilateral triangle, and the vertical angle of the developed side will be equal to the angle formed by the two sides of a pentagon.

In the construction for the icosaedron, *Figure* 5, as each solid angle is composed of five sides, and as all the sides of the solid are equilateral triangles, the base of the pyramid is a pentagon, and the developed side an equilateral triangle.

In the construction for the dodecaedron, *Figure* 4, the

angle of the pentagon was found by dividing a circle into five equal parts, and joining the chords of two adjoining parts, as A B, B C, *Figure* 4, No. 1. Then, to obtain the vertical angle, draw A C as a base; bisect the angle A B C, which will also bisect the straight line A C in E; make E F equal to the half of B C, No. 2, and draw F G parallel to B C, cutting B D at G; make E G, No. 2, equal to E G, No. 1; and in No. 2 join G B and G C, which will give the vertical angle B G C.

PROBLEM XIX. *To project the dodecaedron.*

Figure 6.—Find *a b c d e*, the orthography of one of the planes, by Problem VII.; find the angle which two contiguous planes of the solid make with each other, by Problem XVIII.; find the intersection of each of the planes adjoining to the plane whose projection is found, by Problem XIV., and thus three of the arrises of the solid will be projected; then, to project the planes adjoining the extremities of the arrises, or edges, *a b*, *a e*, *a h*, suppose that contiguous to *a b*, produce *b c* to meet the intersecting line X Z in *o*, and produce *b f* to meet X Y in *p*; join *o*, *p*; then, having the projection of the angle *c b f*, and the projected lengths, *c b* or *b f*, of one of the sides, and the intersecting line, *o p*, of the plane of that side, find the orthography, *c b f m l*, of the whole figure, by Problem VIII. In like manner, find the orthography of the figures *g h i q r*, *k s t d c*, and the representation of the solid will be completed.

PROBLEM XX.—*To divide the representation of a circle into parts representing the original circle divided into equal parts.*

Plate VI. *Figure* 1.—Let A B C D be the original circle, and let *a b c d* be its orthographic representation. Suppose the first part of the original circle to commence at the given point, E; let E F, F G, G H, &c. be the equal parts in the original circle, and let O be its centre; join E O, F O, G O, H O, &c.; let the diameter, B D, be perpendicular to the intersecting line, I N, and let A C be parallel to I N; then *b d* and *a c* being the representations of B D and A C, draw *b a* and B A, and let B A cut the radii E O, F O, G O, H O, &c. in the points K L M N, &c.; draw K *k*, L *l*, M *m*, N *n*, &c. cutting the representative chord, *a b*, at *k l m n*, &c. Let *o* be the representative centre; draw *o k*, *o l*, *o m*, *o n*, &c., and produce *o k*, *o l*, *o m*, *o n*, &c. to meet the circumference of the representative circle in *e*, *f*, *g*, *h*, &c.; then will *e f*, *f g*, *g h*, &c. be the representations of the equal parts E F, F G, G H, &c. of the original circle: and if the representative radii, *e o*, *f o*, *g o*, *h o*, &c. be produced to meet the opposite parts of the curves at *e'*, *f'*, *g'*, *h'*, &c., *e' f'*, *f' g*, *g' h*, &c. will also represent equal parts.

In the same manner, if B C, and its representation, *b c*, be joined, the other two representative quadrants may be divided, so as to represent equal parts in the original quadrants remaining; and thus the whole representative circle will be orthographically divided into parts, representing the whole of the original circle divided into equal parts.

To find the orthographical representation of a water-wheel.

Figure 2.—Let No. 1 be the face of the wheel, or its section, perpendicular to the axis: let I N be the intersecting line: draw the ellipsis *a b c d*, representing the original circle, A B C D, divided into equal parts, as in the preceding problem: through the points of division draw the portions of the radii, as intercepted between the orthographic circumferences: draw the ellipsis *e f g*, which will give the orthography of the opposite outer circle: then draw the edges of the boards perpendicular to the intersecting line, I N, so as to be terminated by the orthographic circles *e f g* and *c d a*; then, two of the sides of the float-boards being thus found, the other two may be completed by parallel lines.

The ring which supports the float-boards is represented in the same manner as the orthographic circles, which contain the representations of the float-boards themselves. The radiating pieces, to which the float-boards are attached, are made to tend to the centre, on the side that adjoins the float-boards, and the opposite face is tapered off; and, to accomplish this regularly, it is made to touch the representation of a circle in the same plane.

To project a straight line in a plane, supposing the plane which contains the line to be wrapped round the surface of a cylinder.

Plate XIII. *Figure* 1.—Let A B C D be a cylinder orthographically projected; and let B A be continued to G, so that A G may be equal to the semi-circumference of the cylinder; also let F E be the line to be projected, the point E being in the line A D, and the position of E F to A G being supposed to be given.

Continue the axis of the cylinder to any convenient distance beyond the base A B: at any convenient point in the axis thus produced, describe a circle equal to the radius of the cylinder; draw the diameter H J parallel to A B: divide the semi-circumference H I J into any number of equal parts, as 8; also divide A G into the same number of equal parts; from the points of division in the semi-circumference H I J, draw lines parallel to the axis of the cylinder through the projection A B C D.

Again, from the points of division A G, draw lines perpendicular to the said line A G, to cut the line E F in as many points as A G; from the points of section in E F, draw lines parallel to A B, to cut the former lines drawn parallel to the axis; then the line E F of contrary flexure, is the projection required.

In the same manner the concave line D E, *Figure* 2, is projected from the surface of a cylinder upon a plane into the line D *e*.

To project any line upon the surface of a cone.

Figure 3.—Let A B C be the orthographical projection of the cone on a plane parallel to the axis, and let A B E be the development of the projected surface: then any line B F on this development, will be projected from the conic surface in the following manner:

On B C describe a semicircle B D C, and divide the arc B D C into any number of equal parts; from the divisions of the arc B D C, draw lines perpendicular to B C, to meet it in as many points of section as there are divisions in B D C; from the points of section in the base B C, draw lines to A; from the points of section in the base B E of the development, draw straight lines to A, to cut the line B F intended to be projected; from the points of section in B E, describe arcs from the centre A to cut A B in as many points of section as the number in B F; from every point of section in A B draw lines parallel to B C, to cut each former line respectively; through the corresponding points, draw a curve, as shown by the dark line, and this will be the projection of the line on the conic surface.

Corollary.—Hence the projection may be found according to any given fanciful form, as in *Figure* 4, where *f g* is the projection of E G.

Not only architectural designs, but mechanical drawings, depend upon orthographical representation; it enables the architect, engineer, or mechanic, to construct the object intended to be executed. As drawings of every kind are greatly facilitated by a knowledge of the formation of bodies, so, in drawing machines, it is necessary to know the methods of representing any system of lines upon cylindric and conic surfaces, as this knowledge will determine whether the lines represented are parallel to each other or tend to a point.

In drawing machinery, as in other kinds of orthographical

epresentations, the object is represented upon two planes, one parallel, and the other perpendicular to the horizon.

As the faces of the different parts of a machine are generally in vertical planes parallel to each other, the elevation is also made on a vertical plane parallel to the faces of the work, or to the greatest number of faces, in order to facilitate the execution, as this position not only gives the altitude of the parts, but is also convenient in ascertaining the magnitude of lines in every direction in these planes, and the angles which the lines form with each other; for if the faces of the work stand at oblique angles with the projecting plane, there can be only one direction, namely, that of measuring in a vertical line, in which the true dimensions can be ascertained; every other will be fore-shortened, and the angles formed by the lines of representation will also vary from the original angles of the object.

As the axes of wheels are sometimes obliquely situate, it becomes necessary to represent them in various positions. The several kinds of representations are sections through the principal parts (as through the axis of a wheel), plane or horizontal projections, and elevations.

Though a plan and elevation are sufficient to construct any machine with proper attention, yet from the greater facility of comprehending the nature of the design, and applying the measures to practice, two elevations are sometimes given, particularly in a complex machine. One of these elevations expresses the parts in the longest horizontal dimension of the work, and the other represents the parts comprehended in its breadth, or horizontal extension.

In the representation of a machine, the wheel-work is the most difficult of any part, except when the whole of the surfaces of the wheel are planes, with two or more faces parallel to the projecting plane, and all the other surfaces perpendicular to it, as in this case the boundaries of the parallel planes are represented by figures similar to the original faces, and the whole of the other surfaces are projected into straight lines or circles. This is so very simple, as not to require any directions; but if the wheel, or its faces, have an oblique position to the projecting plane, several considerations are necessary to effect a true representation. A ground section through the axis of the wheel, placed at the required angle, with the intersection of the plane of elevation, and an elevation of the wheel on a plane parallel to the faces, will be required. It is likewise necessary to observe, that, in this oblique projection, all the parallel arrises of any original object are represented by parallel lines, and all equal distances in the original object are represented by other distances equal among themselves; also, all straight lines whatever in the original plane, divided into parts, are represented by a series of parts respectively in the same proportion. The proportion of any line is to its original, as radius to the cosine of the inclination of the original line and the plane of projection. The representation of an original circle is an ellipsis; and as the plane of projection is vertical, the elevation of an ellipsis will be represented with its greater axis perpendicular to the intersecting line.

Problem XXI.—*Given the seat and altitude of a line on a plane, and the intersection of the plane with another plane at a given angle, to find the sun's seat on such plane, as also its angle of altitude.*

Plate VIII. *Figure* 1.—Let A C, No. 1 and 2, be the seat of the line; A B the intersection of the last named plane. In A C take any point, C; draw C D perpendicular to A C; draw C E perpendicular to A B, cutting A B at B. In No. 2, draw C H perpendicular to B C; make C H equal to C D, and the angle C B G equal to M L K, No. 3, the inclination of the planes; draw H G perpendicular to B G; make B E equal to B G, and join A E; then A E will be the seat of the sun's rays on the plane, as required. Draw E F perpendicular to A E; make E F equal to G H, and join A F; then E A F will be the angle of altitude of the line on the same plane.

In No. 1, the two planes are at right angles to each other; in this case, the problem may be constructed without the quadrilateral B C H G; thus, having drawn C E perpendicular to A B, cutting A B at B; make B E equal to C D, and complete the triangle A E F, as in No. 2; then A E will be the seat of the line, and E A F the angle of altitude, as before.

This may easily be conceived, by supposing, that upon the triangle A B C, No. 2, the triangle A C D, and the quadrilateral B C H G, are raised perpendicularly; then C H and C D will coincide, and the point H will coincide with the point D; turn the triangle A B E upon A B, and the side B E, being perpendicular to A B, will describe a plane upon B E, perpendicular to the plane A B C; and because B C and B E are in the same straight line, B C will be in that plane; and because the plane B C H G, is supposed to be raised perpendicular to the plane A B C upon B C, the plane supposed to be described by B E will be in the same plane with B C H G, when raised perpendicularly to the plane A B C; therefore, move the plane A B E till B E coincide with B G, supposed to be raised with the plane B C H G; the planes A C D, B C H G, and A B E, being thus supposed to be raised, turn A E F round A E, till E F falls upon G H; then the point F will fall upon H; and the straight line A F will also be coincident with A D; for the triangle A E F will be at a right angle with the triangle A E B; therefore E F will be at right angles to the plane A B E.

Problem XXII.—*Given the seat and altitude of the sun's rays on a plane, and the angle which the seat of a line parallel to the plane of projection makes with the seat of the sun's rays; to determine the inclination of the plane of shade obstructed by the original line towards the plane of projection.*

Figure 2.—Let A C be the seat of the sun's rays given upon the plane of representation; make C A D equal to the altitude of the sun's rays; draw C D perpendicular to A C; make C A B equal to the angles made by the seat of the sun's rays with the seat of the original line, which occasions a plane of shade; from C draw C B perpendicular to A B, and C E perpendicular to C B; make C E equal to C D, and join B E; then C B E will be the inclination of the plane required. Produce C B to F; make B F equal to B E, and join A F; then let the triangles C A D, C B E, B A F, be turned up, and A F and A D will coincide; and the triangle C B E will measure the inclination of the plane A B F to C B A. This problem is of the utmost use in finding the shadows of parallel lines to planes in various positions; as also in finding the shadows of cylinders where the axis is parallel to the plane of projection; and in determining the points and lines of light and shade in cylinders and cylindric rings.

Problem XXIII.—*Given the seat and altitude of a line and the seat and altitude of the sun's rays; to determine the shadow of the line on that plane.*

Figure 3.—Let H E be the seat of the line; make the angle, E H I, equal to the altitude of the line, viz., of A B C, No. 1; E being any point in H E; draw E I perpendicular to H E; draw E F parallel to the seat of the sun's rays; and draw E G perpendicular to E F; make E G equal to E I; make the angle E G F equal to the complement of the sun's altitude, and join H F, which will be the shadow of the line required.

This problem will be of great use in finding the shadows of objects upon inclined planes.

PROBLEM XXIV.—*Given the inclination of a line to two planes at right angles to each other; to find the seat of the line on each of the planes, and the intersection of the planes.*

Figure 4.—Let A B C, No. 2, be the inclination, or angle, made by the line with one of the planes, and D E F, No. 3, the angle it makes with the other.

From the angular point, B, No. 2, take B C, of any length, and from the angular point, E, No. 3, take E F equal to B C; in No. 2, draw C A perpendicular to A B; and, in No. 3, draw F D perpendicular to E D; in No. 1, draw any line G K; and through G, any point in G K, draw H I perpendicular to G K; make G H equal to the sine, D F, of one of the angles of No. 3, and G I equal to the sine, A C, of the other, No. 2; from H, with the radius, A B, No. 2, describe an arc, cutting G K at K; and join H K and K I; then G K will be the intersection of the planes, and K H and K I will be the seats of the line on each of them.

In the following problems, respecting shadows, two planes of projection are always supposed to be given, viz., the seat of the rays of light on each of the planes, and the intersection of the planes, unless otherwise announced.

Practical examples of shadows.

Example 1.—*To find the shadow of a rectangular prism attached to a wall, one of the sides of the prism coinciding with the surface of the wall.*

Figure 5.—Let H I K L M N be the plan, the straight line, H I M N, that of the wall, and I K L M that of the prism; let A B C D be the elevation of the prism, and V W the intersection of the plane of elevation with that of the ichnography, parallel to H N, and K L in the plan.

To find the shadow of any point, B, *on the elevation, corresponding to* L *on the plan.* Draw the ichnography, L N, of a ray of light; also, from B, draw B F, the elevation of the ray, at any given angle with the intersection V W; join B L; draw F N parallel to B L; and the point F will be the shadow of the point B on the elevation.

In the same manner, find E and G, the shadows of the points A and C; join E F and F G; and A B C G F E A will be the shadow required.

Or, find the shadow, F, of the point B, as before; draw the indefinite representations, A E and C G, of the extreme rays; then, because the arrises, or edges, of the prism are parallel to the wall, or to the surface on which the shadows are thrown, the representations of the edges of the shadows will be parallel to the representations of the arrises on the plane of elevation; therefore draw F E parallel to A B, and F G parallel to B C; and A E F G C will be the edge of the shadow, as before.

Example 2. *Plate* IX.—The shadow of *Figure* 1 is found in the same manner as in the last example; the body which throws the shadow being a prism, with its planes parallel and perpendicular to the surface on which the shadow is thrown; A N M L C is therefore the outline of the shadow thrown by a prism, represented by F G H I on the plan, and by A B C D on the elevation. The figure here introduced represents a cantiliver projecting from a wall.

Example 3.—*To find the shadow of a cantiliver, formed as in the last example, the plane of elevation being placed obliquely to the surface on which the shadow is thrown.*

Figure 5.—Let E F I K be the representation of the surface on which the shadow is projected, placed obliquely to the line V W, the intersection of the orthographic planes; let F G H I be the plan of the cantiliver, and A B C D its elevation, the points A and D on the elevation corresponding with the point H on the plan, and the points B and C corresponding with the point F. The end of the cantiliver is represented by D *e f* A, and the root by C *g h* B; the point I, on the plan, being represented by *g* and *h* on the elevation, and the point F, on the plan, by B and C on the elevation. To find the shadow of any corresponding lines, F G and B *h*; draw G L, the parallel of the seat of the sun's rays on the plan, meeting the shadowed surface, E K, in L; draw L *m* perpendicular to V W; from *h*, the corresponding point of G, draw *h m*, the elevation of the ray; join B *m*; draw *g o* parallel to B *m*; draw *m n* parallel to A B, and *n o* parallel to A D; then *h m n o g* will be the shadow required: for the representation of the two edges of the shadows are parallel to the representation of the two edges of the end of the cantiliver.

Example 4. *Figure* 3.—Let A B D E be the intersection of any vertical surface on which a shadow is to be thrown; also let B C D be the plan of a triangular prism projecting from that surface; and G H I F its elevation; find *p n*, the shadow of the perpendicular line, as before; and join *n* G; then will *p n* G be the shadow of the prism, as required.

Example 5. *Figure* 4.—G H I K L is the elevation of several rectangular prisms joined to each other in the form of a pediment; G H I K L is the outline, and *l m n* the inner line, forming the tympanum; A B E F is the plan of the surface on which the shadow is to be thrown, parallel to the intersecting line, V W; B C D E is the plan of the pediment, of which the line C D, representing the face, is parallel to A F. Draw G O, H P, I G, and *n r*, the elevation of the rays; also, draw the ray D *v* on the plan, meeting A F at *v*; *v* P G perpendicular to the intersecting line, cutting the rays, H P and I G, of elevation, at P and G: draw P O parallel to G H; then G O P G I will be the extremity of the shadow, as in Example 1. To find the shadows from the inner edges, *l m* and *n m*, make *n r* equal to G O, or H P, or I G, as each of the points, G, H, I, *r*, is equally distant from the surface; draw *r s* parallel to *n l*, and *r t* parallel to *n m*; then will *s r t* represent the shadow from the under arrises of the inclined parts.

Example 6.—*Figure* 5, is the shadow of several rectangular prisms crossing each other at equal angles; one of the faces of each is parallel to the plane on which the shadow is thrown, and also to the plane of elevation; the opposite, or parallel faces, are attached to the plane on which the shadow is thrown, and, therefore, the other faces are perpendicular to such plane. The shadows are to be found as in the last example, viz., by drawing indefinite rays from all the angular points on the elevation, and finding the length of one of them; then the rest will be completed by parallel lines from the termination.

Example 7.—*To find the shadow of a rectangular ring.*

Figure 6.—Find the point, *l*, the shadow of the centre, *k*; through *l* draw O P perpendicular to *k l*; then, with the radius of the interior circle, describe the arc, W X U, meeting the said inner circle in W and U; also, from *l*, with the radius of the exterior circle, describe the semicircle, O Q P; draw O M and P N parallel to *l k*, and these lines will touch the circle in M and N; then M O Q P N will represent the exterior shadow required.

PROBLEM XXV.—*Given the sun's seat and inclination on the plane of the horizon, and the intersection of two planes at right angles with each other, and perpendicular to the horizon; to find the representation of the sun's rays on each of the vertical planes.*

Plate X. *Figure* 1.—Let A D and D B be the intersection of the two vertical planes, and A B the seat of the sun's rays on the horizon; make the angle, A B C, equal to the angle of the sun's altitude; draw A C perpendicular to A B and A E perpendicular to A D: make A E equal to A C, and join E D, which will represent the ray of the sun, on the plane of which the intersection is A D: produce A D to G; make D G

equal to A C, and join G B; and G B will represent the sun's ray, on the plane of which the intersection is D B.

This problem is necessary in the three preceding examples, when the seat and inclination of the sun is given on the horizon, in order to find the orthography of the ray upon both elevations, viz., upon the front and end.

PROBLEM XXVI.—*To find the representation of the shadow on a prismatic solid, by a plane cutting the prism perpendicular to its arrises; given the elevation of the prism on a plane parallel to its arrises, and parallel to one of its sides: as also the figure of the plane which throws the shadow, with the section of the surfaces of the prism on that plane, and likewise the sun's rays, both on the plane and on the elevation.*

Place the figure of the plane and the elevation so that any two of their corresponding points, or parts, may be in a line perpendicular to the intersection. Draw the representation of the rays from all the angular points on the figure of the plane, to meet the sectional line of the prism; draw the corresponding representations of the rays on the elevation, and from the points where the representation from the angles of the plane meet the section, draw lines parallel to the representations of the arrises of the prism to cut the corresponding rays on the elevation; then, by joining the successive points, the shadow required will be determined.

Example 1. *Figure* 2.—Let A B C D be the plane, and E F, F G, the intersection of two other planes at right angles to A B C D; let K L N O be the elevation of the prism; the lines O N, R M, and K L, representing the arrises corresponding to the angular points, G, F, E, on the section,—that is to say, the point G is in the same straight line with O N, the point F with R M, and the point E with K L; also, let K L M R represent the plane parallel to the plane of elevation, and let K P represent the line of intersection; make K U equal to the breadth of the shadow at the bottom; draw the ray, D I, on the figure of the plane, and D T perpendicular to K P, cutting K P at T; and T will represent the point which throws the shadow on the elevation; draw T Q, the ray of the sun, on the elevation; I Q parallel to D T, and U S parallel to K P, cutting R M at S; join S Q; then K U S Q V O will be the representation of the shadow required.

Example 2.—*Figure* 3 shows the shadow of a chimney-shaft upon the roof of a house, the sides of the shaft being parallel and perpendicular to the front.

Example 3.—*Figure* 4 shows the shadow of a chimney-shaft upon a roof, which has two inclinations; the sides of the shaft being situate as in *Example* 2. The principles of performing these two examples are the same as in the preceding problem. *Example* 2.

PROBLEM XXVII.—*To find the indefinite shadow of a line perpendicular to the horizon on an inclined plane: given the inclination of the plane to the horizon, and the seat of the sun's rays: the intersection of the inclined plane with the horizon being parallel to the intersection of the plane of representation and the horizon.*

Plate XI. *Figure* 2, No. 3.—Draw any straight line, A B C; make A B to A C, as the sine is to the cosine of the plane's inclination; make the angle, C A D, equal to that of the seat of the sun's rays, with a line perpendicular to the intersection of the horizon and the plane of representation; draw C D perpendicular to A C, and join B D; and B D will be the indefinite representation required.

PROBLEM XXVIII.—*To find the shadow of a plane rectilinear figure intersecting another plane figure: a point through which the shadow is to pass on the plane which receives the shadow, and the orthography of the rays of the luminary, being given.*

If the line which throws the shadow meets the intersection of the planes, draw a straight line from the point of concourse through the given point, and the line thus drawn will be the indefinite representation of the shadow. But if the line which throws the shadow does not meet the intersection of the planes, continue the line or the intersection of the plane, or both of them, as the case may require, to meet each other, and draw a straight line from the point of concourse through the given point, as before; and the line thus drawn will be the shadow required.

PROBLEM XXIX.—*Given the orthography of a determinate line, and the indefinite representation of its shadow, also, the orthography of the sun's rays, to find the limits of the shadow.*

From one, or either of the terminations of the line, as the case may require, draw the orthography of a ray to cut or meet the indefinite shadow of the line, and the length comprehended between the point, or points, thus found in the shadow, will be the extremity, or will terminate the length, as required.

Example 1.—*To find the shadow of a chimney-shaft on the roof of a house.*

Plate XI. *Figure* 1.—Find the indefinite shadow of the vertical line, F L, No. 2, thus: let A C, No. 3, be parallel to F L: find B D, as in PROBLEM XXVII: draw F O, No. 2, parallel to B D, No. 3: now let the parallel of the orthography of the sun's rays be given: from L draw L O, the orthography of the sun's rays, and the point O is the termination of the shadow, F O; produce F G and L M to meet each other in N; draw O N, and it will give an indefinite representation of the shadow of the edge, L M, of the top; draw the orthography, M Q, of the ray, parallel to L O, cutting O N at Q; continue the intersection, G H, and the edge M L, of the top, to meet each other in P; draw Q P, and it will give the indefinite representation of the edge of the top, and of the other vertical plane not seen; draw H R parallel to F O, and F O Q R H will represent the shadow required.

Example 2.—*Figure* 2, is the shadow of a dormer window with a rectangular front, and the top inclined towards the front: find the indefinite shadow, A G, as in the last example, and the orthography, F G, of the sun's rays; join B G, and A G B will represent the shadow, as required.

Example 3.—*Figure* 3, is the shadow of a dormer window, with a pediment top: find A G, the shadow of A E, as before; then D E being the next line that projects a shadow, A B is the intersection of the plane, A B C D E; therefore, produce D E and B A to meet in F; join F G, which produce to H; find the termination, H, by the rays, H; and A G H E will represent the shadow, as required.

Note.—If the lines D E, E G, had been in the same straight line, or had formed a salient angle, instead of a re-entrant one, the upper side of the shadow would have been the same as in the last example.

Example 4.—*Figure* 4, exhibits the shadow of a dormer window with a semicircular head: find the shadow, A I of the perpendicular line A F; let O be the centre of the semicircular head; draw D L to touch the head of the window at D, parallel to the orthography of the sun's rays; draw O D perpendicular to D L, and D will be the point of contact.—Now, let it be required to find the shadow of any intermediate point, E, of the arc of the circle: A B is the intersection of the plane A B C D E F; therefore draw the chord, E F, and produce A B and E F to meet each other in H; produce H I to K; and draw the orthography, E K; and the point K will represent the shadow of the point E. In like manner, draw the chord D E, and produce D E and B A to meet each other in G; join G K; produce G K to L; and L will represent the shadow of the point D: draw a curve from the point I,

through K to L, touching the straight line A I and D L at the points I and L; and A I K L D will represent the shadow, as required.

Example 5.—*Figure* 5, exhibits the shadow of a dormer window with a kirb-roof top; find the shadows, M, K, I, of the points E, F, G, as in the last example; and A I K M E F G A will represent the shadow required.

It is hardly possible to conceive a method more expeditious, than the foregoing, of finding the indefinite representation of the shadow, by producing the line which throws it, and the intersection of the plane, till they meet each other in the plane in which the shadow is thrown.

Example 6.—*Plate* XII. *Figure* 1, No. 1, is the elevation of a prismatic object, as the walls of a building, which form two prisms attached to each other; the lower prism is terminated with an inclined plane, in the manner of a roof. The plan, No. 2, shows the end of the higher prism, to which the lower prism is attached, to be at an obtuse angle with the plane of the front.

Let the ray, B F, No. 2, be drawn on the plan from the corner B, to meet the side C D at F; then F is the projected point of B on the plan; draw *f g*, the elevation of the point F, cutting the top of the lower wall at *g*; draw *l m*, the elevation of the sun's ray, as in the preceding examples; produce the intersection, *h i*, of the inclined plane to meet the line, *b l*, which projects the shadow in *k*; through the points, *k* and *g*, draw *k g m*, meeting the elevation of the sun's rays at *m*. Now, as the line, *l o*, of the top of the end of the prism projects the next shadow, produce *l o*, and the intersection, *i h*, to meet each other in *n*; draw *m n*, cutting the upper termination, *h q*, of the inclined plane at *r*; and *f g m r h i e f* will represent the shadow required.

Example 7, *Figure* 2, No. 1, is a plane figure, representing the gable of a house, of which B A is the base; F G, G H, H U, are the intersections of several planes; F G, parallel to B C, is the intersection of a vertical plane, as the face of a wall; G H and H U are the intersections of two inclined planes, forming two sides of a kirb-roof. Now, to find the shadow, by the intersecting points of the lines which project the shadow with the plane on which the shadow is thrown, it is evident that the line, B C, will project a shadow on the plane, whose intersection is F G, parallel to F G; and as B C, No. 2, represents B C, No. 1, draw *p q* parallel to B C, cutting the lower inclined plane at *q*. Then, supposing the side, B C, also to throw a shadow upon the lower inclined plane, produce its intersection, H G, No. 1, and the line, B C, which throws the shadow, to meet in K; produce C B, No. 2, to *k*, and draw *k k* parallel to B A; then through the points, *k* and *q*, draw *k q r*; draw C C from C, No. 1, to C, No. 2, parallel to B A, No. 1; from the point, C, No. 2, draw the elevation, C *r*, of the sun's rays. C D, No. 1, is the next line, which throws the shadow still upon the lower inclined plane; therefore, produce C D and G H to meet each other in M; draw M *m* parallel to B A, cutting B C at *m*; draw also the indefinite shadow, *r m*, cutting the intersection of the two inclined planes at *s*, No. 2; then the line, C D, will also project a shadow upon the upper inclined plane; therefore, produce H U and C D, No. 1, to meet each other in N; draw N *n* parallel to B A, cutting B C at *n*; draw the indefinite shadow, *s n*; then *d*, No. 2, being the corresponding point of D, No 1, draw the elevation of the ray, *d t*, No. 2; and the point, *t*, No. 2, will be the shadow of D, No. 1. D E, No. 1, is the next line that projects a shadow, and U is the intersection of D E and H U, and *u* the corresponding point to U, No. 1; therefore join *t u* and B *p q r s t u* will represent the shadow required.

Example 8, *Figure* 3, represents an example, similar to *Figure* 1, but with two inclined planes; the plan is here omitted, as being only used in the projection of the first ray; the ray, G L, parallel to A B, is drawn at pleasure at any distance from F H, to meet the intersection, H P, of the two adjoining planes in L; produce J H to meet the line A B, which throws the shadow in D; draw D L, and produce D L to S; draw the elevation of the ray B S; then B C is the next line which throws the shadow; produce B C and H J to meet each other in E; draw the indefinite shadow, S E, to cut the intersection, I Q, of the two inclined planes at M; then B C will also project a shadow upon the upper plane; therefore, produce B C, and the intersection, J K, of the upper plane, to meet each other in T; draw the indefinite shadow, M T, cutting the top, K R, at N; then F G L S M N K will represent the projection of the shadow by the edges A B, B C, of the plane, A B C, as required.

This figure may either represent the vertical plane, A B C, or perpendicular to the first vertical plane, F O P H, according as the sides are parallel or oblique to the plane of representation.

Example 9. *Figure* 4.—Let A B C D E, be the figure of a gable; K L M N the upright of a wall; A B the base of the gable; N M the base of the wall; and suppose that the edge, B C, is joined to N K at any given angle, so that the point B may coincide with the point N. Now, let it be required to find the shadow of the gable, A B C D E, upon the wall, K L M N, the side, B C, of the gable being placed parallel to the edge, N K, of the wall: as the vertical sides, A E and B C, of the gable are parallel, the shadow thrown upon the plane, K L M N, will also be parallel to the edge, N K; therefore, taking N *g* at pleasure, draw *g h* parallel to N K; then, *e* being the corresponding point of E, draw *e h*, the elevation of a ray of the sun, and the point *h* will be the shadow of the point E. E D being the next line that projects the shadow, produce E D and B C, the intersection of the plane, to meet in F; find *f*, the corresponding point of F, and draw the indefinite shadow, *h f*; find *d*, the corresponding point of D, and draw the elevation, *d i*, of a ray, cutting *h f* at *i*; C being the concourse of the line which throws the shadow with the intersection, B C, of the plane, find *c*, the corresponding point of C, and join *c i*; then *c i g h* will represent the shadow of the lines A E, E D, and D C.

Example 10. *Figure* 5.—A B C D E represents the gable of a building, as in the preceding example; S T U V the upright wall and inclined side of a roof; F G and G I the respective intersections of the wall and the roof; then supposing the edge, E D, of the gable to be attached to S *b*, it is required to find the form of the shadow; the intersection, F G, of the plane being parallel to A B, the breadth of the shadow will also be parallel; therefore, taking the distance, S *n*, upon S V at pleasure, draw *n o* parallel to S T; then, *b* being the corresponding point of B, draw the elevation, *b o*, of the ray: B C being the next line which projects the shadow, produce the intersection, F G, to meet B C in L; find *l*, the corresponding point of L, and draw the indefinite shadow, *o l*, cutting *b* W at *p*; B C now projects the shadow upon the inclined plane; therefore, produce the intersection, G I, and the edge, B C, that throws the shadow, to meet in K; find *k*, the corresponding point of K; through *k* and *p* draw the indefinite shadow *k p q*; *c* being the corresponding point of C, draw the elevation, *c q*, of a ray: find *i*, the corresponding point of I; and join *i q*, which completes the shadow on both planes.

PROBLEM XXX.—*A cylinder being capped with a square abacus, jutting alike over each of the sides, to find the representation of the shadow; the elevation and plan being given, as also the plan and elevation of the sun's rays.*

Plate XIII. *Figure* 1, No. 1.—Let A B C D be half the plan of the abacus, E F G half the plan of the cylinder, H I J K the elevation of the same, and L M N O that of the abacus; to project the shadow of any point, p', in the elevation of the abacus, p being its corresponding place on the plan; draw the plan of the ray, $p\ q$, meeting the semi-circumference E F G at q; also from p' draw $p'\ q'$ the indefinite elevation of the ray; and draw $q\ q'$ parallel to I J, or H K, and q' will represent the shadow of the point p'. Find as many other points as may be necessary, in the same manner; then, through all the points thus found, draw a curve, which will be the shadow required.

If the ray, R T, be drawn to touch the circle in V, on the plan, and if V′ V″, the elevation of V, be drawn, then V′ V″ will be the line of separation of light and shade.

If the rays of the sun be in two planes, one perpendicular to the plane of representation, but inclined 45 degrees to the horizon, and the other equally inclined to the horizon and to the plane of representation; that is to say, making 45 degrees with each; then all the points, q', will be in the circumference of a circle, whose diameter is equal to the diameter of the cylinder.

No. 2, shows the elevation completely shadowed.

Problem XXXI.—*A cylinder being capped with another concentric cylinder, to find the representation of the shadow.*

Figure 2, No. 1.—Proceed to find all the points, q', as in the last problem, and a curve being traced through them will give the shadow required. The point p', on the elevation, corresponding to p, on the plan, may be thus found: draw B R parallel to A C, and A R perpendicular to A C; draw p S parallel to A R, cutting B R at S. In L M make L p' equal to R S, and p' will be the corresponding point of p. No. 2 shows the elevation completely shadowed.

Projection, *Stereographical.* See Stereography.

Projection of Shadows, *see* Shadows.

PROJECTURE, in architecture, the out-jettings, or prominence, which the mouldings and members have, beyond the plane, or naked, of the wall, column, &c. They are called by the Greeks, *ecphoræ;* by the Italians, *sporti;* by the French, *saillés;* by our workmen frequently, *sailings over;* and by the Latins, *projecta*, from *projicio, I cast forward;* whence the English, *projecture.*

Vitruvius gives it as a general rule, that all the projecting members in buildings have their projectures equal to their heights: but this is not to be understood of the particular members, or mouldings, as dentils, coronas, the fasciæ of architraves, the abacus of the Tuscan and Doric capital, &c., but only of the projectures of entire cornices, &c. The great point of building, according to some modern architects, consists in knowing how to vary the proportions of projectures, &c., agreeably to the circumstances of the building.

Thus, say they, the nearness and remoteness, making a difference in the view, require different projectures; but it is evident the ancients had no such intention.

The projecture of the base and cornice of pedestals, M. Perrault observes, is greater in the antique than in modern buildings, by one-third; which seems to follow, in good measure, from the ancients proportioning this projecture to the height of the pedestals; whereas the moderns make the projecture the very same in all the orders, though the height of the pedestal be very different. The reason of this change, which the moderns have made of the antique, the same author refers to a view of the appearance of solidity.

PROLATE (from the Latin *prolatus*, flat) an epithet applied to a spheroid produced by the revolution of a semi-ellipsis about its longer diameter. If the solid be formed by the revolution of a semi-ellipsis about ts shorter diameter, it is called an *oblate spheroid;* of which figure is the earth we inhabit, and, perhaps, all the planets too; having their equatorial diameter longer than the polar.

PRONAOS, (from προναος) in ancient architecture, a porch in front of a temple, church, palace, or other spacious building.

PROPORTION, (French) the just magnitude of the members of each part of a building, and the relation of the several parts to the whole; *e. gr.* of the dimensions of a column, &c., with regard to the ordonnance of the whole building.

One of the greatest differences among architects, M. Perrault observes, is in the proportions of the heights of entablatures with respect to the thickness of the columns, to which they are always to be accommodated. *See* Entablature. There is scarcely any work, either of the ancients or moderns, in which this proportion is not different; some entablatures are even nearly twice as high as others: yet it is certain, that this proportion ought, of all others, to be most regulated: none being of greater importance, as there is none in which a defect is sooner observed, nor any in which it is more shocking.

Proportion is likewise understood of the magnitudes of the members of architecture, statues, or the like, with regard to the distance whence they are to be viewed.

The most celebrated architects are much divided in their opinions on this subject; some will have it, that the parts ought to be enlarged in proportion to their elevation; and others, that they ought to remain in their natural dimensions.

PROPORTIONAL COMPASSES, an instrument consisting of two equal and narrow slips of metal, terminating at each extremity in a point, the slips being connected together by a cylindric pin, which, when they are made to coincide, is moveable along a slit through both pieces: so that the axis, or centre of the pin, and the two extreme points of each piece, may be in the same straight line, and fixed at any point which will keep its situation in each of the pieces, whether the instrument be opened at any angle, or shut.

The two surfaces of the instrument which appear when it is shut are called *the sides.*

The four parts of the instrument, from the centre of motion, are called *legs.*

It is evident from the definition given, that two legs will be equal to each other, and of the same invariable length, whatever angle these legs make with each other; and that the two which include the opposite angle will also be equal to each other, and their length also invariable at any angle formed by them.

The application of the proportional compass with regard to the division of lines, and the circumferences of circles into any number of equal parts, has already been shown under the articles Compasses and Instruments. In this place it is proposed to treat of its application to perspective, and some other branches of geometry and architecture.

Problem 1.—*To set the proportional compasses in the ratio of a line divided into any two parts.*

Figure 1.—Take a line equal to the length of the instrument, and divide it in the ratio required; then apply the shorter or longer part of the line thus divided on the length of the instrument when shut, from the extremity of the longer or shorter legs to an intermediate point, to which bring the axis of the pin, and the compasses will be set in the ratio required. Thus, let A D, be a straight line, divided in E; make A B equal to the length of the instrument; join D B, and draw E C parallel to D B, cutting A B at C; shut the instrument; take either distance, C A or C B, say the shorter, C B, and apply it from the shorter end of the instrument; push

the slider along the slit until the centre of the pin coincides with the other extremity, and the instrument will be set in the ratio required.

As this problem is essential to most of the following, the reader is requested to understand it thoroughly before he proceeds farther.

Problem II. *Figure* 2.—*Given any number of lines,* A B, C D, E F, G H, *&c., to find a series of other lines, which will have the same ratio in every two corresponding lines, given one line* a b, *of the series required, corresponding to* A B *of the series given.*

Set the proportional compasses in the ratio of A B to *a b* by Problem I.; then if A B be greater than *a b*, take the distance, C D, with the remote extremities, and make *c d* equal to the distance contained between the near extremities, and *a b* will have the same ratio to *c d*, which A B has to C D: in like manner, take the distance, E F, with the remote extremities, and make *e f* equal to the distance contained between the points of the near extremities, and *c d* will have the same ratio to *e f*, that C D has to E F; or *a b* will have the same ratio to *e f*, that A B has to E F, and thus the remaining lines, *g h*, &c., will be found in the same manner; but if the line, A B, in the given series, be less than *a b*, in the given line of the series required, the lengths, C D, E F, &c., must be taken with the shorter ends of the compasses, and the lines, *c d*, *e f*, &c., made respectively equal to the corresponding distances contained between the extremities of the longer ends.

Problem III.—*To divide a given line in the same proportion as another given line is divided.*

Figure 3.—Let A X be a given line, divided into the parts, A B, B C, C D, D X, and let it be required to divide the line, *a e*, in the same proportion.

Set the compasses in the ratio of the whole lines A X and *a e*, then take the distances, A B, B C, C D, D E, with the same legs which were applied in taking the distance A X, and with the other legs corresponding to the distance *a e*, make *a b*, *b c*, *c d*, *d e*, respectively equal to the distance between the points of these legs, and *a b*, *b c*, *c d*, *d e*, will have the same ratio to each other, that A B, B C, C D, D X, have to each other.

Problem IV.—*To divide a straight line,* A X, No. 2, *in continued proportion; given the extreme part,* A B.

Set the compasses in the ratio of A X to B X by Problem I.; contract the points of the longer legs to B X, then, with the shorter legs, cut off the distance X C; again contract the distance between the points of the longer legs to X C, thus found, and with the shorter legs cut off the distance X D; and thus, by setting the distance between the points of the longer legs to the last distance found, the shorter legs will give the succeeding part by transferring the distance between the shorter legs from X towards A. By continuing this operation, as many points may be found as are necessary for the purpose required; then A B : B C : C D : D E : E F : F G, &c; that is, A B : B C : : B C : C D; and B C : C D : : C D : D E, &c.

Any question in the rule of three may be resolved by the proportional compasses and a plane scale. Thus, suppose three articles of the same kind to cost two shillings; what will eight cost? Set the compasses in the ratio of 2 to 3 by Problem I.; extend the points of the shorter legs to 8 on the scale: then apply the longer legs to the scale, and 12, the measure indicated, will be the fourth proportional, as required.

Where there is a great disproportion in the terms of the ratio, it would be more eligible to use two scales; thus, suppose it were required to find a fourth proportional to the numbers 30, 3, and 45, take any convenient scale for the antecedents, 30 and 45, and any convenient larger scale for the consequents, 3; then, by Problem I. set the compasses in the ratio of the distance 30, on the scale of the antecedents, to the distance 3 in the scale of the consequents; then take 45 from the scale of the antecedents with the legs first applied to the same scale, and the other legs will give the distance 4.5, or $4\frac{1}{2}$, the answer as required, by applying the distance between their points on the scale of the consequents.

By this, any proportion, whether in lines or numbers, may be resolved.

Problem V. *Figure* 4.—*Given two straight lines,* A B *and* C D, *tending to an inaccessible point, and a point,* E, *in position, to draw a straight line through the last-named point, so that all the three straight lines,* A B, C D, *and that which is required to pass through the given point, may have the same point of concourse.*

Through the given point, E, draw F G, meeting A B at F, and C D at G; draw H I parallel to F G, cutting A B at H, and C D at I: set the proportional compasses in the ratio of the two straight lines, F G and H I; then, F G being greater than H I, take the distance G E, with the longer legs, and make I K equal to the distance between the points of the shorter legs; draw a straight line through the points E and K; then if the straight lines A B, C D, and E K, be produced, they would have one common point of concourse.

Corollary. Figure 5.—Hence, if A B and C D be two straight lines, and if E, G, I, L, be several points in a straight line, P O, meeting A B in P, and C D in O; then drawing any line, R S, parallel to P O, cutting A B at R, and C D at S, and setting the proportional compasses in the ratio of P O to R S; (P O being longer than R S,) take the distance O E, O G, O I, O L, with the longer legs, and apply the distances contained between the points of the shorter legs respectively from S to F, from S to H, from S to K, and from S to M; and drawing the lines, E F, G H, I K, L M, they would all have one common point of concourse, if produced with A B and C D.

Figure 12 shows the application of this problem and its corollary, in drawing the representations of the horizontal lines which regulate the heights of doors and windows in the perspective representation of a building, when the vanishing points of the sides, A *k* and A *h*, are not in the picture, and when all the points, through which these lines pass, are in the corner of the building, or any other convenient line.

Problem VI. *Figure* 6.—*Given two straight lines,* A B *and* C D, *tending to an inaccessible point, and any number of points,* E, G, I, *in position, not in a straight line; to draw a right line through each of the points* E, G, I, *tending to the same point with* A B *and* C D.

Through the point E, draw any line, A C; through the point G, draw L M, parallel to A C, cutting A B at L, and C D at M; and through the point I, draw N O, also parallel to A C, cutting A B at N, and C D at O; draw any line, I Q, parallel to A C; set the proportional compasses in the ratio of A C to I Q; take the distance C M, C O, with the longer legs, and make Q R, Q S, respectively equal to the distances contained between the points of the shorter ends; draw R T, S U, parallel to P Q, cutting A B in T, U; make Q *e*, R *g*, S *i*, respectively equal to C E, M G, O I; and draw the straight lines, E *e*, I *i*, G *g*, which will tend to the same point with A B and C D.

Figure 7 is added to show the great use of these problems in perspective, and completely exemplifies this problem by showing, that if any section of the original object made by the plane of the picture be obtained, such as the mouldings on the face of a building, it will be very easy to draw lines from all the points of such a section that will tend to the proper vanishing points, two lines tending to the same point being given.

Problem VII. *Figure* 8.—*Given the representation, a'' b'' c'' d'' e'' f'', of one end of a right cylinder, (the original*

having its axis parallel to the picture,) and the vanishing line, u z, of the plane of that end; through a given point, a, in any perpendicular, a'' a, to u z, to draw the representation of the other end of the cylinder.

Let *a'' a* cut the vanishing line, *u z*, at *u*; draw *b'' b*, *c'' c*, *d'' d*, *e'' e*, *f'' f*, parallel to *a'' a*, cutting *u z* respectively at *v*, *w*, *x*, *y*, *z*; set the proportional compasses in the ratio of *u a''* to *u a*; then *u a''* being greater than *u a*, take the distance, *v b''*, with the longer legs, and make *v b* equal to the distance contained between the points of the shorter ends; find the remaining points, *c*, *d*, *e*, *f*, in the same manner, and through the points, *a*, *b*, *c*, *d*, *e*, *f*, draw a curve, which will be the representation of the other, or lower, end of the cylinder.

Or, if the base, *a*, *b*, *c*, *d*, *e*, *f*, were given, the top would be found in the same manner, by making the ratio of the shorter legs to the longer legs, as *u a* to *u a''*, and taking *v b* with the nearer extremities, and making *v b''* equal to the distance of the remote extremities, and finding the remaining points, *c''*, *d''*, *e''*, *f''*, in the same way. In like manner, any section, *a'*, *b'*, *c'*, *d'*, *e'*, *f'*, may be found.

This application of the proportional compasses is exceedingly useful in the representation of bows, when required in the fronts of buildings, as is shown by *Figure* 9, which exhibits the elementary lines of the perspective of a house. Here the horizontal terminations of the apertures are readily represented, by only drawing perpendicular lines, which may be the vertical terminations of such apertures, and would therefore be required at all events. The same description of words applies to this figure, as in *Figure* 8, to which the problem refers.

Problem VIII.—*Given the representation of any point on the picture, and the intersecting and vanishing lines of the plane it is in, to find the height of a representative line, the original of which is parallel to the picture.*

Set the proportional compasses in the ratio of the distance between the intersecting and the vanishing lines, and the distance of the point from the vanishing line, then take the length of the original line with the longer legs, and the opposite points will give the height of the line required.

Example—Suppose the distance between the vanishing and intersecting lines to be three inches, and the distance between the representation of the point or foot of the line to be two inches, and the height of the original line to be six inches, required the perspective height of the same. Set the proportional compasses in the ratio of 3 to 2; extend the longer legs of the compasses to six inches, and the extent between the opposite shorter legs will be the height of the line required, which, in this case, will be four inches.

Scholium.—By this method all the heights of the representation of a solid may be found without any additional lines; but, in order to expedite the work, when the original object is of different heights in the same plane parallel to the picture, or where the same height is required to be found upon two or more points, it will be eligible to draw a straight line through one of the points, cutting the one or more lines on which the heights are to be found; and the same setting of the compasses will do for as many heights as are to be raised upon the line so drawn.

Example.—Suppose a cylinder [illegible] e represented, its base is an ellipsis, to find any two po[illegible]n the height of the cylinder; draw a straight line, para[illegible]o the vanishing line, to cut the representation of the base [illegible] the cylinder in two points; upon each point of section dr[illegible] a perpendicular; set the proportional compasses in the ratio [illegible] the distance between the intersecting and vanishing lines, [illegible] either point and the vanishing line; then take the height o[illegible]he cylinder between the points of the long legs, and the distance between the opposite points will give the perspective height upon each perpendicular from its respective foot.

In the application hitherto made of the proportional compasses, the sides of the instrument have not required any gradations of parts; but as these are necessary to the perfection of the instrument, the construction of the scales for this purpose is as follows.

Problem IX.—*To construct the scales of sines for the proportional compasses.*

Figure 10.—Let A C be a scale of sines found in the usual manner; and let C A be produced to R, making A R equal to the radius; draw R D at any convenient angle with R C; make R D equal to the length of the proportional compasses, and join C D; draw A 9 parallel to C D, and as 9 at the point C is the chord of 90°, the point 9, in R D, will be the point for the index of the slider to be set to; then if the legs of the compasses be set to any angle, the distance between the points corresponding to D will be to the distance between the points corresponding to R, as the sine of 90° is to radius. In like manner, join D 8, the next point, 8, in the line A C, and draw A 8 parallel to D 8, cutting R D in 8; then the point, 8 in R D, will be the point for the index of the slider to be set to; then, if the ends of the proportional compasses, corresponding to R, be opened to any radius, the extent of the ends corresponding to D is the sine of 80 degrees corresponding to that radius: in like manner, the points 6, 5, 4, 3, 2, 1, will be found in R D, so that 1, 2, 3, 4, 5, 6, 7, 8, 9, in R D, are the gradations on the side of the proportional compasses corresponding to 10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°, 90°; hence if the index be set to any of these numbers. and the points correspon[illegible]ng to R be extended to the radius, the distance between the opposite points will be the sine of that number of degrees. The cosines have the same divisions as the sines, but are numbered the contrary way.

In the same manner, by placing the radius in the same straight line with a common scale of sines or tangents from zero on A, so as to lengthen the line A C, of tangents, by adding the said radius, A R, and forming the extension, R C, drawing R D at any convenient angle with R C and dividing R D as in the problem; then R D will contain the gradations of a scale of tangents, to be inserted on the side of the proportional compasses: so that when the index, or mark, upon the slider is brought to any of these numbers, the end corresponding to R being opened to the radius, the end corresponding to D will be the sine or tangent of the angle corresponding to that number. See the *Figure*.

Figure 11 shows the application of the method to a scale of tangents.

Example 1. *Figure* 13.—To make an angle of 30° at a given point, A, in the straight line A B.

With any convenient radius, A B, describe an arc, B C; set the index to 30° on the line of chords; then extend the points of the instrument corresponding to R, to the radius A B, and with the opposite points set off the distance B C, on the arc, and join C A; then C A B is the angle required.

Example 2.—To find the tangent of 40° to any given radius within the limits of the points corresponding to R.

Set the index to 40° on the line of tangents, and extend the points R to the radius; then the extent between the opposite points will be the tangent of 40°, as required.

Example 3.—To find the sine of 20° to any given radius within the limits of the points corresponding to B.

Set the index to 20° on the line of sines, then extend the points corresponding to R to the radius given, and the extent between the opposite points will be the sine of the angle, as required.

Example 4.—To find the cosine of 50°, the radius being given within the limits of the instrument.

Set the index to 50° on the line of cosines; extend the points corresponding to R to the radius, and the opposite points will be the cosine of the angle required.

Example 5.—The chord, sine, cosine, or tangent, of any number of degrees being given, to find the radius.

Extend the points corresponding to D to the chord, sine, cosine, or tangent, and the opposite points corresponding to R will be the radius of the circle required.

PROBLEM X.— *To draw the representation of a house, by making the centre of the picture the dividing point, having the dimensions of the building given.*

Figure 12.—Let V L be the vanishing line, *h k*, the intersecting line, and C, the centre of the picture; and let the building touch the intersecting line in A; also, let the vanishing points of the sides be supposed to be given.

Set the proportional compasses to the cosine of the angle which the one side of the building (viz., say that on the right) makes with the intersecting line by *Example* 4, Problem IX., say 30°; then, with the ends of the instrument corresponding to R, take the original measure from a plan; or, if the measures are known in feet, &c., take them from a scale, without being at the trouble of drawing a plan; take the distance of the corner of the building, and the nearest side (say 3 feet 6 inches) from the scale, with the remote points, and with the opposite points set off the distance A b on the intersecting line; take the breadth of the window from the scale (say 3 feet) with the remote points, and with the opposite points set off the distance b c, on the intersecting line; take the breadth of the next pier from the scale (say 4 feet) with the remote points, and with the opposite points set off the distance c d: proceed in this manner to h, so that the whole extent, A h, will represent a distance of 24 feet. Next proceed to the end of the building, which is supposed to be on the left hand; here, as the angle of the building is supposed to be a right angle, and as the right-hand side was supposed to make an angle of 30° with the intersecting line, the left-hand side will therefore make an angle of 60°; set the index of the proportional compasses to 60° in the line of cosines; then, from the scale, take the breadth of the end (say 20 feet) with the remote ends, and with the opposite ends set off the distance, A k; set the breadth of the piers from k to j, and from A to i, in the same manner, draw the lines A h and A k to the vanishing points of the sides.

From the points, b, c, d, e, f, g, h, as also from i, j, k, draw lines to C, cutting A *h* at *b, c, d, e, f, g, h*, and A *k* at *i, j, k:* from the points of section draw perpendiculars to V L; set the heights of the apertures, and the height of the building itself, upon the corner A A′; say that the sills of the lower windows are three feet high, the windows six feet, the space between the lower windows and the upper, four feet, the upper windows four feet also, and the distance to the parapet three feet; therefore make A *l* equal to three feet, *l m* equal to six feet, *m n* equal to four feet, *n o* equal to four feet, and *o* A′ equal to three feet, exactly to the scale or natural measures of the building: from these points of section draw lines to the vanishing points, and complete the whole representation. In setting up the heights, common dividers may be used. By the last setting of the proportional compasses, if the thickness of the walls are taken from the scale by the remote ends, marked R, and the distance of the two opposite points be set upon the intersecting line from the points, c, e, g, towards A; and if, from the points of section, lines be drawn to C, the centre of the picture, to cut the representative base line, A *h*, of the building, and perpendiculars be drawn from the points of section in A *h*, these perpendiculars will give the reveals of the windows; that is, they will show the thickness of the walls on the sides of the windows.

PROBLEM XI.—*Given the vanishing line of a plane, its centre and distance, and the inclination of a line in that plane to the intersection; to find the vanishing point of the line without drawing any lines in the vanishing plane, in order to find the vanishing points of the original line, as given in position to the intersecting line.*

Figure 14.—Let the angle made by the original line with the intersection be 30°; subtract 30° from 90°, and 60° will remain; bring the index of the proportional compasses to 60° on the line of tangents; extend the extremities of the compasses, marked R, to the radius; then set the distance of the opposite extremities from C to *v*, on the vanishing line, V L, and *v* will be the vanishing point of the line, as required.

The proportional compasses will answer to any distance of the eye from the vanishing line, however great, by taking one-half, one-third, one-fourth, &c. of the distance of the vanishing line, as most convenient, with the extremities marked R; then repeating the distance between the points of the opposite extremities, twice, three times, four times, &c., accordingly.

By this method, the vanishing point of every original line, of any plane figure, may be found without having the point of sight placed in a perpendicular to the vanishing line from the centre of the picture. This will be very convenient, as the extension is entirely confined to the vanishing line, and thus it requires the paper to be of no greater breadth than what is sufficient for the picture intended.

Example.—Let it be required to find the vanishing points of a rectangle, supposing the right-hand side to be placed at 40° with the intersecting line.

Subtract 40° from 90°, the number contained in a right angle, and the remainder, 50°, will give the angle made by the primary, or shortest radial, and the radial of the right-hand side, or the angle made by the original side of the rectangle on the right-hand, and a perpendicular in the original plane to the intersecting line; then the angle contained between the primary radial and the radial of the left-hand side of the rectangle will be 40°. Now, suppose the length of the picture to be 12 inches, and the spectator to stand at 2 feet, or 24 inches, from the centre of the vanishing line; and suppose the proportional compasses to be 6½ inches, which is the usual length: divide 24 into 6 equal parts, each of which, in this instance, will contain 4 inches; slide the index of the instrument to 50° on the line of tangents; then with the legs R, take the extent of 4 inches, or the sixth part of 2 feet, and repeat the distance of the opposite points on the vanishing line, from the centre, C, of the picture, towards the right-hand, six times, to *v*, and *v* will give the vanishing point. To find the vanishing-point of the left-hand side: as the radial of this side makes 40° with the primary radial, slide the index of the instrument to 40° on the line of tangents; then, with the legs marked R, take the extent of 4 inches, or the sixth of 2 feet; repeat the distance between the points of the opposite ends from the centre of the picture towards the left hand, six times to v, and v will be the vanishing point on the left-hand side of the rectangle.

The vanishing points of all lines whatever may be found in this manner, having the angle formed by the intersecting line and the original: for this is always equal to the angle formed by the radial and the parallel of the eye; and because the distance of a vanishing point from the centre of the picture is the tangent of the angle made by the primary radial and the radial of the line, the primary radial being radius, the proportional compasses, being set as above, will give the true vanishing point.

Scholium.—None of the lines on the proportional compasses, except the tangents, require the slit to be less than half the length of the shank, deducting that part of the slide from the centre of the pin; the tangents, therefore, cannot be inserted higher than 45°; and, indeed, the higher tangential numbers would be of little use, as the radius would be shortened by every such increase: and it would be attended with greater inaccuracy and more labour. If the gradations, however, do not exceed 45°, the distance of the extremities of the compasses may still be extended to six inches: but, in order to find the tangent of any greater number of degrees than 45, we have only to subtract that number of degrees from 90, and the remainder is the complement of the angle; then it will be as the tangent of the complement is to radius, so is radius to the tangent itself.

From these observations it will be very easy to find the vanishing point of any line, whatever number of degrees the radial of that line forms with the primary radial, as may be seen in the following problem.

Problem XII.—*To find the vanishing point of a line, the radial of which makes a greater angle with the primary radial than* 45°, *the vanishing line and its centre being given, as also the primary radial.*

Subtract the given angle from 90°; set the index of the compasses to the tangent of the remaining angle; take a convenient aliquot part of the distance of the eye from the vanishing lines, and set the legs marked R, to that distance; upon any imaginary straight line, A E, with the ends R, set off the distance A B; take the distance A B, with the opposite ends, and set off the distance A D; then let V L be the vanishing line, and C its centre; and, according as the original line, or its radial, is on the right or left, the distance, A D, must be set to the right or left of the centre of the picture, as often as the radial is supposed to contain the distance of the points upon the legs marked R.

Example.—Suppose the radial of the line to make an angle of 50° with the primary radial, and the length of the primary radial to be three feet; to find the distance of the vanishing point from the centre of the picture.

Subtract 50° from 90°, and the remainder is 40°; set the index to the tangent of 40°; take the ninth part of the primary radial, or 4 inches, and extend the ends opposite to those marked R, to 4 inches, or the ninth part of the distance, and repeat the distance of the legs marked R, on the vanishing line, nine times from the centre to the right or left hand accordingly; and the extremity of the distance so repeated from C, is the vanishing point required.

The reason of this operation is evident; since the radius is a mean proportional between the tangent of the angle and the tangent of its complement, and, therefore, as the tangent of the complemental angle is to the radius, so is the radius to the tangent itself.

If the object to be drawn be a rectangle, making unequal angles with the intersecting line, the angles made by the radials of the sides and the primary radial, being equal to the angles made by the sides of the rectangle and the intersecting line, or a line drawn through the outer corner parallel to the intersecting line; set the proportional compasses to the tangent of the least angle; extend the legs marked R to the distance, or to any part of the distance that the compasses will admit of; set the distance of the opposite legs, or repeat that distance as often as the primary radial contains parts, from the centre to the right or left, and the point of extension will give the vanishing point of that side of the rectangle; extend the ends opposite to R to the primary radial, or that portion of it before-mentioned, that the compasses will admit of, and the extension between the extremities of the legs marked R, being set from the centre on the other side of the vanishing line, or repeated according to the number of parts into which the primary radial is divided, will give the vanishing point of the other side of the rectangle, viz., of that side which makes the greatest angle with a line perpendicular to the intersection; and therefore the vanishing point so found must be upon the same side of the centre of the picture that the angle itself is upon, being nothing more than the tangent of that angle.

Scholium.—The vanishing points of a rectangular building may be found arithmetically upon the foregoing principles, viz., as the tangent of the angle made by the radial of one side and the primary radial is to the primary radial itself, so is the primary radial to the tangent of the angle made by the radial of the other side and the primary radial. Now, admitting the shortest tangent to be to the primary radial as 2 to 3, and the length of the primary radial 3 feet 6 inches, or 42 inches; to find the vanishing points, it will be

3 : 2 : : 42
2
—
3) 84
—
28 inches, the distance of the vanishing point of the least angle.

And again, 2 : 3 : : 42
3
—
2) 126
—
63 inches, the distance of the vanishing point of the greater angle.

Or, because the distance is a mean proportional between the two tangents, it will be

28 : 42 : : 42
42
—
84
168
—
28) 1754 (63 inches, the tangent
168 of the greater angle
—— as before.
84
84

When the distance of the vanishing points is required, the square root of the sum of the squares of each tangent, and the primary radial, will give the distance from each respective vanishing point; but if the vanishing points be inaccessible, subtract each tangent from the respective distance so found, and set the remainder on each side of the centre of the picture.

This method of finding the distance would be thought by many artists very troublesome; but the following, by the proportional compasses, is very easy: Suppose one radial to make an angle of 30°, the other will be 60° with the primary radial; add 30° to 90°, the sum will be 120°; take the half of 120, which is 60; then 30 from 60, there remains 30; the tangent of 30°, set upon the other side of the primary radial, will give the distance of the vanishing point. Again, add 60 to 90, the sum is 150, the half is 75°; subtract 60 from 75, and the remainder is 15°; then the tangent of 15°, set from the centre of the picture on the other side of the angle of 60°, will give the distance of the vanishing point of the line that makes 30° with the intersection.

Again, suppose one of the angles to be 40°, the other will

be 50°; add 40 to 90, the sum is 130; the half of 130 is 65; subtract 40 from 65, and the remainder is 25°; then the tangent of 25°, set on the other side of 40 from the centre of the picture, will give the distance of the vanishing point of the line, the radial of which makes 40° with the primary radial. Again, add 50 to 90, the sum is 140, the half is 70; subtract 50 from 70, and the remainder is 20°; then, the tangent of 20° being set from the centre of the picture upon the other side of the angle formed by the primary radial, the other radial, containing 50°, will give its distance.

In general, suppose the lesser angle to be called v, and the greater w; then $\frac{v+90}{2} - v = \frac{90 -}{2} = 45 - \frac{v}{2}$, and the tangent of this angle, set upon the other side, will give its vanishing point.

Again, $\frac{w+90}{2} - w = \frac{90-w}{2} = 45 - \frac{w}{2}$, gives the distance of the other vanishing point, set on the contrary side of the centre; thus, if $w = 60$, then $45 - \frac{w}{2} = 15$, therefore set the tangent of 15° as directed; and thus the tangent of the remainder of half the angle contained by the primary radial and the radial from 45°, gives the vanishing point; or, take the tangent of half the complement of the said angle, and set it on the vanishing line from the centre of the picture on the other side, and it will give the vanishing point.

Problem XIII.—*Given the angle made by the radials of any two original lines with each other, and the angle which one of them makes with the primary radial; to find a dividing point common to the same measures or scale, so as to cut off a portion from the indefinite representation of each line, such that the portions may be the representations of the two original lines.*

Note.—When one of the angles which the primary radial makes with the one radial is given, that made by the primary radial with the other may be found by subtracting the one given from the whole angle contained by the radials. This being obtained, proceed as follows:—Subtract the lesser angle formed by the one radial and the primary radial from half the angle contained by the radials of the original lines; then, if the tangent of the remaining angle be set on the vanishing line, on the side of the primary radial which has the greatest angle, it will give the dividing point required.

Thus, call the whole angle A; the half is $\frac{A}{2}$; call the lesser angle made by the primary radial with one radial, B, then $\frac{A}{2} - B$ is the difference; find the tangent of $\frac{A}{2} - B$; then the greater angle made by the primary radial with the other radial being $A - B$, set the tangent of $\frac{A}{2} - B$ from C, on the vanishing line on the side of $A - B$, and the extremity of the distance will give the dividing point required.

Example 1.—Suppose the angle contained between the two radials to be 100°, and the lesser angle to be 40°, then the greater will be 60: now the half of 100 is 50: subtract 40°, the lesser angle, from 50, there remains 10: set the index of the proportional compasses to 10° on the line of tangents; take the length of the primary radial with the legs marked R, and set off the distance contained by the opposite points from the centre of the picture on the vanishing line, on the side of the primary which has the angle of 60°, and the extremity of the distance is the dividing point.

Example 2.—Suppose the angle contained by the radials to be 80°, the lesser angle to be 30°, and consequently the greater 50°; the half of 80° is 40°; subtract 30° from 40°, and 10° remain. Set the index of the proportional compasses to the tangent of 10°; take the length of the radial with the legs marked R, and set the distance of the point contained by the opposite legs from C on the vanishing line, on the side of the angle of 50°, and the extremity will give the dividing point.

Problem XIV.—*Given the sun's altitude on a plane, the height of a line, and the length of its shadow on that plane; the orthographical representation of a cornice, with a section of the same, also the seat of the sun's rays; to find the shadow of the cornice.*

Figure 15.—Let No. 1 be the cornice or architrave, and No. 2 a profile, or section, perpendicular to the arrises, or edges of the mouldings; draw *b* B for the indefinite representation of the shadow of a line represented by the point *b*, No. 1, and let *b* B be the distance that the shadow is thrown from the point *b*, so that B will be the shadow of *b*; from all the external angles draw *c* C, *e* E, *g* G, I H. Now *k l*, No. 2, is the length of the line represented by the point *b*, No. 1: set the proportional compasses in the ratio of *k l*, No. 1, to *b* B No. 2: make *c* C equal to *b* B: take *o p*, No. 2, with the shorter ends, and make *e* E, No. 1, equal to the distance between the points of the remote ends; take *q r*, No. 2, with the shorter legs, and make *g* G, No. 1, equal to the distance between the points of the remote ends; join B C; draw C D parallel to M *c*, and draw E D parallel to *e d*; draw E F parallel to *e* K, and G F parallel to *g f*; draw G H parallel to *g* I; and *b* B C D E F G H I will be the shadow from one side: draw the lines M L, K J, parallel to *b* B, *c* C, &c., to meet K *h* and I *i* at L and J; then will M L and K J be the shadows upon the other side. To find the shadows upon the planes of the face: in the representation, *c* M, of the arris line, take any point, *v*, and draw *v w* parallel to *b* B, or *c* C, &c.; also, in the representation, *e* K, of the next arris line, take any point, *x*, and draw *x y* parallel to *b* B or *c* C; take the distance *d c*, with the shorter ends of the proportional compasses, and make *v w* equal to the distance between the points of the longer legs; also, take the projection, *f e*, with the shorter legs, and make *x y* equal to the distance contained between the points of the remote ends; through the points *w* and *y* draw L *u* and J Q parallel to M *c*, which will terminate the breadth of the shadow upon the face.

The reason of this operation is evident, since the distance that a shadow will be thrown by a line perpendicular to a plane, is as the length of the line: and the shadow of a line parallel to a plane will be projected on the plane parallel to the line which projects the shadow; and every two parallel lines in the original object are also represented by parallel lines.

Problem XV.—*The representation of a cylinder with a square abacus, or cap, being given, to find the shadow of the cap upon the cylindric surface, the axis of the cylinder being parallel to the plane of projection; also, the shadow of a line perpendicular to the axis of the cylinder, and in a plane passing along the said axis, and through the luminary.*

Figure 16.—Let A B C D E F G be the plan of the semi-cylinder, and H I M N that of the cap; let W X Y Z be the elevation of the semi-cylinder, and *i m v u* that of the cap; let I B be the projection, or representation, of a ray on the plan, from the corner of the abacus at I, cutting the plan of the cylinder at B; draw L F parallel to I B, to touch the semicircle in F, and cutting I M at L; draw F V perpendicular to L F, V being the centre of the semicircle; and F will be the point of contact: in I M take any number of intermediate points, J, M, K, and draw J C, M D, K E, parallel to I B, cutting the

semicircle in C, D, E; draw B *p*, C *a*, D *r*, E *s*, F *t*, parallel to the axis of the cylinder, cutting the under edge, *i m*, of the abacus in *p*, *a*, *r*, *s*, *t*; set the proportional compasses in the ratio to the distance to which I B will throw the shadow, and suppose I B to be greater than the length of its shadow; take the distance, I B, with the longer legs; make *p b* equal to the distance contained between the points of the opposite ends; take the distance, J C, with the longer legs, and make *a c* equal to the distance contained between the shorter legs; take the distance, M D, with the longer legs, and make *r d* equal to the distance contained between the opposite points; and the points, *b*, *c*, *d*, will be obtained. In the same manner, the points *e* and *f* will be found; through the points, *b*, *c*, *d*, *e*, *f*, draw a curve, which will be the shadow of the lower edge of the abacus; the sun's rays will be in a tangent plane to the cylinder surface at F *f*: and the part of the edge of the shadow which falls upon the representation of the cylindric surface, from *i* to *b*, will be straight.

In the same manner, if the representation of a cylinder capped with a cylindric abacus, having the same axis with the cylinder, be given, and the representation of the sun's rays on the plan, supposing the axis of the cylinder perpendicular to the plane of projection, the shadow of the abacus may be found upon the cylindric surface; and thus for every other prismatic object.

PROBLEM XVI.—*To describe the logarithmic spiral by a series of points found in the curve; the centre, and two opposite points in a straight line passing through the centre, being given in the curve.*

Figure 17.—Let Z, No. 1, be the centre; let the straight line, A E, pass through Z; let A and E be two opposite points, the one, A, on the one side, and the other, E, on the other side of the centre, Z; through Z draw G C at right angles to A E; bisect the angle A Z C, by the straight line B F; also bisect the angle E Z C, by the straight line D H; find Z C, a mean proportional between Z A and Z E; also find Z B, a mean proportional between Z A and Z C; draw any straight line, *a* x, No. 2, and set the proportional compasses in the ratio of Z A to Z B; take the distance, Z A, with the points of the longer legs, and set that distance from x to *a*, No. 2, and make x *b* equal to the distance contained between the shorter legs; contract the points of the longer legs to x *b*, and with the shorter legs set off the distance x *c*; contract the distance between the points of the longer legs to x *c*, and make x *d* equal to the distance contained between the points of the shorter legs; and the parts, *a b*, *b c*, *c d*, of the straight line, x *a*, will be in geometrical progression. In the same manner, the points *e*, *f*, *g*, *h*, *i*, &c., may be found, which will continue the series of parts as far as there may be occasion; make Z A, No. 1, equal to x *a*, No. 2, Z B equal to x *b*, Z C equal to x *c*. In the same manner, the points, D, E, F, G, H, I, &c., may be continued through any number of revolutions; and a curve drawn through all the points will give the spiral required.

Scholium.—As the tracing of the curve depends very much on the eye of the person who performs this operation, by the following method a curve may be drawn with a pair of compasses, provided the points do not approach very rapidly to the centre. To describe any quadrant, take the length of the radius that bisects it from one extremity of the curve, describe an arc, and with the same radius from the other extremity describe another arc cutting the former; then, from the point of intersection with the same distance, describe an arc between the two extremities, and it will pass through the middle point, very nearly; thus, take the distance Z B as a radius; from the extremity A, of the arc A B C, describe an arc near the centre; from the point C, with the same radius, describe another arc, cutting the former near the centre Z; then, from the point of intersection, describe the arc A C, which will pass through the point B, very nearly. In the same manner the successive arcs, C E, E G, G I, &c. may be described; and the curve thus formed will be so near as not to be detected by the eye.

PROBLEM XVII.—*To draw the representation of the meridians of a solid of revolution upon a plane parallel to the axis of the solid; given an axal section, that is, a section of the solid, passing along the axis, upon a plane parallel to the said axis.*

Figure 18.—Let *a b c d e v k j i h g f* be the axal section, *q v* the axis itself, and *a f* the base perpendicular to *q v*; in *q v* take any number of points, *r*, *s*, *t*, *u*; through these draw *b h*, *c i*, *d j*, and *e k*, perpendicular to *q v*, meeting the curve on the one side at *b*, *c*, *d*, *e*, and on the other at *h*, *i*, *j*, *k*; then it is obvious that the lines *b h*, *c i*, *d j*, *e k*, will be bisected; now, supposing the meridians to be formed on the surface of the solid by the intersection of five planes at equal angles round the axis, and that one of these planes is parallel to the plane of projection, and let *a v f a* be the representation of that plane; draw A B parallel to *a f*; produce *v q* to meet A B at *w*; from *w* as a centre, with the radius *q a*, or *q f*, describe the semicircle A 1 2 3 4 B; divide the semicircle into five equal parts by the points of section 1, 2, 3, 4; draw 3 *x* and 4 *y* perpendicular to A B, cutting A B at *x* and *y*; make *q l* equal to *w y*; set the proportional compasses in the ratio of *q a* to *q l*; take the distance *r b*, with the longer legs, and with the opposite legs set off the distance *r m*; take the distance *s c*, with the longer legs, and with the opposite points set off the distance *s n*; take the distance *t d*, with the longer legs, and with the shorter legs set off the distance *t o*; lastly, take the distance *u e*, with the longer legs, and with the shorter legs set off the distance *u p*; then draw the curve *l m n o p v*, which will be one of the meridians, as required. In the same manner all the others may be found.

Besides the uses of the proportional compasses, which have already been shown, they may be applied to trigonometry in finding the sides and angles of triangles; suppose, in a right-angled triangle, that the two legs were given, to find the angles; the analogy is, as the one side is to the other, so is radius to the tangent of the angle opposite the latter side; set the proportional compasses in the ratio of the two sides containing the right angle; then the index will show the tangent of the angle on the line of tangents.

Again, suppose the hypothenuse and one of the legs were given, to find the angles; the analogy in this will be, as the hypothenuse is to the given leg, so is radius to the sine of the angle opposite to that leg; set the proportional compasses in the ratio of the hypothenuse to the given leg, and the index will be against the sine of the angle.

Lastly, suppose the angles and the hypothenuse to be given: the method of proceeding in this case is exactly the reverse of the last; thus, set the proportional compasses to the sine of the angle, then extend the longer legs to the hypothenuse of the angle, and the shorter legs will contain the length of the leg required.

In the same manner, if the angles and one of the legs were given, to find the other leg; set the proportional compasses to the tangent of the leg required, then take the length of the given leg with the longer legs, and the distance between the points of the shorter legs will be the leg of the triangle, as required.

PROPYLÆA, (Greek προ, before or in front of, and πυλον a gate) the entrance to a temple or other large building, consisting mostly of a gateway flanked by towers or other erections. The Egyptian temples were universally adorned with magnificent propylæa, which consisted of lofty truncated

pyramids of solid masonry, covered on the faces with hieroglyphics.

The term is also particularly applied to the entrance of the acropolis of Athens, which was erected by Pericles, and was of unusual magnificence.

PROPYLON, an entrance or vestibule.

PROSCENIUM, (Greek) in the ancient theatre, an eminence on which the actors performed their parts. The proscenium answered to our stage. It consisted of two parts among the Greeks; one, particularly so called, where the actors performed; the other was the *logeion*, where the singers and the mimics acted their parts. Among the Romans, the proscenium and pulpitum were the same.

PROSTYLE, (from the Greek προστυλος, formed from προ *before*, and στυλος, *column*) in the ancient architecture, a range of columns in the front of a temple.

PROSTYPA (from προστυπα) images carved in such a manner as to be only half raised above the ground, or plain, on which they are formed. They seem to adhere to it, and have only one side exposed to view. To *prostypa* is opposed *ectypa*.

PROTHYRIS, (Greek) in ancient architecture, a word sometimes used for a cross-beam, or over-thwart rafter; as likewise, for a quoin or corner of a wall; otherwise called *anco*. *See* CONSOLE.

PROTHYRUM, (from προθυρον) a porch at the outer door of a house, or portal.

PROTRACTOR, (from the Latin *protractus*, to draw out) an instrument used in surveying, by which the angles taken in the field with a theodolite, circumferentor, or the like, are plotted, or laid down, on paper.

This protractor consists of a semicircular limb of brass, silver, horn, or the like, divided into 180°, and subtended by a diameter, in the middle of which is a little notch, or lip, called the *centre of the protractor*.

For the convenience of reckoning both ways, the degrees are numbered from the left hand towards the right, and from the right hand towards the left.

But this instrument is made much more commodious by transferring the divisions on the same circumference to the edge of a ruler, whose side is parallel to the diameter, which is easily done by laying a ruler on the centre, and the several divisions on the semi-circumference, and marking the intersections of that ruler on the line: so that a ruler with these divisions marked on three of its sides, and numbered both ways, as in the protractor (the fourth, or blank side representing the diameter of the circle) is of the same use as a protractor, and much better adapted to a case.

On the limb of the protractor are sometimes also placed numbers, denoting the angles at the centres of regular polygons: thus, against the number 5, denoting the sides of a pentagon, is found 72, the angle at the centre of a pentagon, &c.

The uses of this instrument are, 1. *To lay down an angle of any given quantity, or number of degrees, at any point, and with any given line.*

Example.—Lay the centre of the protractor on the given point, and the diameter of the protractor on the given line: make a mark against the given degree (say 50) on the limb of the protractor; through which, from the given point, draw a line, and it will give the angle required.

2. *To find the quantity of a given angle.*—Lay the centre of the protractor on the point of the angle, and the diameter on one of the lines forming it. The degree of the limb cut by the other line (*viz.* 50) is the number of degrees of the angle required.

3. *To inscribe any given regular polygon* (*a pentagon for example*) *in a circle.*—Lay the centre and diameter of the circle, and make a dot against the number of degrees of the angle at the centre, *viz.* 72. Through this dot and the centre of the circle draw a line, cutting the circumference of the circle. To the point of intersection, from the point where the diameter cuts the circumference, draw a right line; this line will be a side of the pentagon, which, being taken in the compasses, and set off as often as it will go in the circumference, will give points, which, being connected by lines, will form the pentagon required.

4. *To describe any regular polygon* (e. gr. *an octagon*) *on a given line.*—Subtract the angle at the centre, which the protractor gives (say 45°) from 180; and the remainder, 135, will be the angle included between two sides of the octagon, one-half of which is 67½. Applying then the diameter of the protractor over the given line, with the centre over one extreme; make a dot against 67½, to which, from the centre, draw a line: apply the protractor to the other end of the line, with the centre over the extreme, and there set off another angle of 67½°. From the point where the two lines thus drawn intersect, as a centre, describe a circle with the interval of the given line. The given line will be one side of the octagon; and this set off as often as it will go in the circumference thus drawn, will give points, which, being connected, will form the octagon required.

PROTRACTOR, *Improved*, an instrument much like the former, but furnished with a little more apparatus, so that an angle may be set off to a minute; which is impracticable on the other.

The chief addition is an index fitted on the centre, and moveable on it, so as to play freely and steadily over the limb.

Beyond the limb, the index is divided, on both edges, into sixty equal parts of the portions of circles, intercepted by two other right lines drawn from the centre, so that each makes an angle of one degree with lines drawn to the assumed points from the centre.

To set off an angle of any number of degrees and minutes with this protractor, move the index, so that one of the lines drawn on the limb, from one of the fore-mentioned points, may fall upon the number of degrees given; and prick off as many of the equal parts on the proper edge of the index as there are minutes given; thus, by drawing a line from the centre to the point so pricked off, an angle is obtained with the diameter of the protractor, of the proposed number of degrees and minutes.

PSEUDO-DIPTERAL, (from ψευδο-διπτερος) a temple with eight columns in front, and a single row of columns all round.

The word signifies *false* or *imperfect* diptere; and is used to distinguish this from the diptere, which was surrounded with a double row.

PSEUDO-PERIPTERAL, (Greek, ψευδο-περιπτερος, *false peripteral*,) a term applied to temples in which the columns at the sides are engaged in the wall, instead of being detached from it, as in the true peripteral buildings, the walls of the cella being carried forward to the inter-columniations of the portico.

PTEROMA, the space between the walls of the cella of a temple, and the columns of the peristyle; called also *ambulatio*.

PUDDLING, the method of backing a wall with clay rammed into a compact mass, by means of a beater.

PUG-PILING, the same with *dove-tailed* or *pile planking*.

PUGGING, a coarse kind of mortar laid upon the sound-boarding between joists, in order to prevent sound reaching from one apartment to another.

PULLEY, (from the French, *poulie*) one of the five mechanical powers; consisting of a wheel, or rundle, having a channel around it, and turning on an axis, serving, by means of a rope which slides in its channel, for the raising of weights.

The Latins call it *trochlea;* and the seamen, when fitted with a rope, a *tackle.* An assemblage of several pulleys is called *a system of pulleys,* or *polyspaston:* some of which are in a block, or case, which is fixed; and others in a block which is moveable, and rises with the weight. The moveable wheel, or rundle, is called the *shieve* or *shiver;* the axis on which it turns, the *gudgeon;* and the fixed piece of wood, or iron, into which it is put, the *block.*

The common methods of arranging pulleys in their blocks, may be reduced to two. The first consists in placing them one by the side of another, upon the same pin; the other, in placing them directly under each other, upon separate pins. Each of these methods is liable to inconvenience. Mr. Smeaton, in order to avoid the impediments to which these combinations are subject, proposes to combine these two methods in one. Accordingly, the pulleys are placed in each block, in two tiers; several being upon the same pin, as in the first method, and every one having another under it, as in the second; so that, when the tackle is in use, the two tiers that are the most remote from each other, are so much larger in diameter than those that are nearest, as to allow the lines of the former to go over the lines of the latter, without rubbing. From this construction arises a new method of reviving the line upon the shieves; for here, whatever be the number of shieves, the fall of the tackle will be always upon the middle shieves, or on that next to the middle, according as the number of pulleys in each pin is odd or even. To do this, the line is fixed to some convenient part of the upper block, and brought round the middle shieve of the larger tier of the under block, from thence round one of the same sort next the centre one of the upper block, and so on, till the line comes to the outside shieve, where the last line of the larger tier falls upon the first shieve of the smaller, and being reeved round those, till it comes at the opposite side, the line from the last shieve of the smaller tier again rises to the first of the larger, whence it is conducted round, till it ends on the middle shieve of the upper block on the larger tier.

As a system of pulleys is of no great weight, and lies in a small compass, it is easily carried about, and can be applied, in many cases, for raising weights, where other engines cannot be used. But they have a great deal of friction; because the diameters of their axes bear a very considerable proportion to their own diameters; and because, in working, they are apt to rub against each other, or against the sides of the block, to say nothing of the stiffness of the rope that goes over and under them.

PULLEY, *Doctrine of the.* 1. If the equal weights W and P hang by the cord B B upon the pulley A, whose block, *b*, is fixed to the beam H I, they will counterpoise each other, just in the same manner as if the cord were cut in the middle, and its two ends hung upon the hooks fixed in the pulley, at A and A, equally distant from its centre.

Hence, a single pulley, if the lines of direction of the power and the weight be tangents to the periphery, neither assists nor impedes the power, but only changes its direction.

The use of the pulley, therefore, is when the vertical direction of a power is to be changed into a horizontal one; or an ascending direction into a descending one; and on the contrary.

This is found a good provision for the safety of the workmen employed in drawing with the pulley.

The change of direction by the means of a pulley has this farther advantage; that if any power can exert more force in one direction than in another, we are here able to employ it in its greatest force. For instance, a horse cannot draw in a vertical direction, but draws with all its advantage in a horizontal one. By changing the vertical draught, therefore, into a horizontal one, a horse becomes qualified to raise a weight.

But the grand use of the pulley is, where several of them are combined; thus forming what Vitruvius, and others after him, call *polyspasta;* the advantages of which are, that the machine takes up but little room, is easily removed, and raises a very great weight with a moderate force.

2. If a weight, W hangs at the lower end of the moveable block, *p*, of the pulley D, and the cord, G F, goes under the pulley, it is plain that the half, G, of the cord, bears one half of the weight, W, and the half, F, the other; for they bear the whole between them. Therefore, whatever holds the upper end of either rope, sustains one-half of the weight; and if the cord at F be drawn up so as to raise the pulley D to C, the cord will then be extended to its whole length, except that part which goes under the pulley; and consequently, the power that draws the cord will have moved twice as far as the pulley D, with its weight W, rises; on which account, a power whose intensity is equal to one half of the weight, will be able to support it, because, if the power moves (by means of a small addition) its velocity will be double the velocity of the weight; as may be seen by putting the cord over the fixed pulley C (which only changes the direction of the power, without giving any advantage to it) and hanging on the weight P, which is equal only to one-half of the weight W; in which case there will be an equilibrium, and a little addition to P will cause it to descend, and raise W through a space equal to one-half of that through which P descends. Hence, the advantage gained will be always equal to twice the number of pulleys in the moveable or undermost block. So that, when the upper or fixed block, *u*, contains two pulleys, which only turn on their axes, and the lower or moveable block, U, contains two pulleys, which not only turn upon their axes, but also rise with the block and weight, the advantage gained by this is as four to the working power. Thus, if one end of the rope, K M O Q, be fixed to a hook at I, and the rope passes over the pulleys N and R, and under the pulleys L and P, and has a weight, T, of one pound, hung to its other end, at T; this weight will balance and support a weight, W, of four pounds, hanging by a hook at the moveable block U, allowing the said block as a part of the weight. And if as much more power be added, as is sufficient to overcome the friction of the pulleys, the power will descend with four times as much velocity as the weight rises, and, consequently, through four times as much space. The two pulleys in the fixed block, X, and the two in the moveable block, Y, are in the same case with those last mentioned; and those in the lower block give the same advantage to the power.

It is necessary to observe, that if the lower pulleys do not rise all together in one block with the weight, as in the cases just recited, but act upon each other, and the weight is only fastened to the lowest of them, the force of the power is very much increased, each pulley doubling it. Thus, a power, whose intensity is equal to 8 lb. applied at *a*, will, by means of the lower pulley, A, sustain 10 lb.; a power equal to 4 lb. at *b*, will, by means of a lower pulley, B, sustain the power of 8 lb. acting at *a;* a third power, equal to 3 lb. at *c*, will, by means of the pulley C, sustain the power of 4 lb. at *b*; a fourth power of 1 lb. at *d*, will, by means of the pulley D, sustain the power of 2 lb. at *c;* and this is not altered by having its rope carried over the upper pulley, or roller, E

In the former cases, the force of the power is augmented in an arithmetical proportion of the number of ropes or pulleys; but in this, in a geometrical proportion.

3. If a power move a weight by means of several pulleys, the space passed over by the power will be to the space passed over by the weight, as the weight, to the power.

Hence, the smaller the force that sustains a weight by means of pulleys is, the slower is the weight raised; so that what is saved in force, is spent in time.

Pulley mortise, a longitudinal mortise of considerable length, parallel and near to the under side of the bonding joists, in order to insert the ceiling joists.

PULPIT, an elevated stage or desk, from which orations are pronounced, applied more especially to those employed in churches. They are for the most part of wood, but sometimes of stone, of which an early and beautiful example exists at Beaulieu, Hants. The greater number of examples are of Perpendicular work, and these principally of wood, and polygonal in plan; sometimes with a canopy above. Pulpits are sometimes found outside of buildings, as at Magdalen College, Oxford, and in many instances abroad, where also are pulpits of great size and magnificence, capable of containing more than one person.

PULPITUM, (Latin) among the Romans, a part of the theatre, called also *proscenium*, or what we now call the *stage*, on which the actors trod. Though some say it was properly an eminence on the stage for the music; or a suggestum, whence declamations, &c. were spoken.

The French use the word pulpit, *pupitre*, for a reading-desk in a church, library, or the like; those large ones in churches they properly called *lutrins*.

PULVINARIA, (Latin,) cushions upon which the statues of the gods were laid in the temples, at the time when thanks were given for some signal victory.

PULVINATED, (from the Latin, *pulvinatus*,) in ancient architecture, a term applied to a frieze, which swells, or bulges out, in manner of a pillow, *pulvinus*: whence the name.

PUNCHION, or Puncheon, (from the French, *poinçon*,) a little block or piece of steel, on one end of which is some figure, letter, or mark, engraven either in creux, or in relievo; impressions of which are taken in metal, or some other matter, by striking it with a hammer. There are various kinds of these puncheons used in the mechanical arts. Such, for instance, are those of the goldsmiths, cutlers, pewterers, &c.

Punchion, is also a common name for all the iron instruments used by the stone-cutters, sculptors, locksmiths, &c., for the cutting, inciding, or piercing their several matters.

Those of sculptors and statuaries serve for the repairing of statues, when they are taken out of moulds.

The locksmiths use the greatest variety of punchions; some for piercing hot, others for piercing cold; some flat, some square, some round, others oval; each to pierce holes of its respective figure in several parts of locks.

Punchion, or Punchin, in carpentry, a piece of timber placed upright between two posts, whose bearing is too great, serving, together with them, to sustain some heavy weight.

The punchion is usually lower and slighter than either prick-posts or principal posts, and is joined by a brace, or the like, of iron. *See* Post. Those on each side of a door are called *door punchions*.

Punchion is also a piece of timber raised upright under the ridge of a building, in which the little forces, &c., are jointed. Vitruvius calls the punchion *columen*.

Punchion, is also used for the arbor or principal part of a machine, on which it turns vertically; as that of a crane, &c.

PUNT, a sort of oblong flat-bottomed boat, with a square head and stern, whose floor resembles the platform of a floating stage; used by shipwrights for breaming, caulking, or repairing a ship's bottom. It is also used in some canals.

PURBECK STONE, (the *saxum arenarium cinereum Purbecense* of Da Costa, and *psadurium friabile albido fuscum* of Hill,) an alkaline sand-stone, harsh and rough, of a disagreeable ash-colour, very heavy, and moderately hard; of a texture not very compact, but somewhat porous, and composed of an angular grit, cemented together by an earthy spar: it cuts freely, and with a tolerably even or smooth surface. It will not strike fire with steel, and burns to a white colour. The quarries of this stone are in the island of Purbeck, in Dorsetshire, whence it is brought to London in great quantities, and there used in building, and for pavements. Its specific gravity is 2.68. There is also another kind of Purbeck stone, the *saxum fusco-albidum* of Da Costa, and the *sympexium durissimum splendidum albido-fuscum* of Hill, which is alkaline, of a dull disagreeable pale-brownish white colour, and cuts to a very smooth surface: it is of a fine, close, compact texture, not quite destitute of brightness, but full of sparks of pure spar, and intimately mixed with vast quantities of small pectunculi, which are often saturated and filled with the same substance; is very heavy and hard, and water does not pervade its texture; it does not strike fire with steel, and when burnt acquires a clear ashen colour. This stone is brought from Purbeck, and used in building, pavements, &c. Hill informs us, that it is likewise found in many other parts of the kingdom, and that there are large strata of it in Yorkshire.

PURFLED, (from the French, *pourfiler*, to embroider,) ornamental work, whether in stone or other materials, representing drapery, embroidery, or lace-work.

PURLINS, pieces of timber lying across the rafters on the inside, to keep them from sinking in the middle of their length.

Purlins are supported by the principals. The strongest method is to make bridges over, as in the present practice of the construction of roofs.

PUTEAL, (from the Latin, *puteolus*, a well,) among the Romans, a small kind of edifice raised in the place where a thunder-bolt had fallen.

PUTLOGS, or Putlocks, short pieces of timber, about seven feet long, used in building scaffolds. They lie at right angles to the wall, with one of their ends bearing upon it, and the other upon the ledges or poles which stand parallel to the side of the wall of the building.

PUTTY, (from the French, *potee*,) a kind of paste, compounded of whiting, with or without a little white-lead, and linseed oil, beaten together to the consistence of a tough dough; used by glaziers for fastening the squares of glass in sash-windows, &c., and by painters, to stop up the crevices and clefts in timber and wainscot, to prevent the wet from getting in and ruining the work.

PUZZOLANA, or Pozzolana, a kind of substance formed of volcanic ashes, more or less compacted together, so called from Pozzuolo, as also *pulvis Puteolanus*, from Puteoli, situate near mount Vesuvius, from which these ashes are ejected, and in the vicinity of which it abounds. It occurs of various colours, white, red, or black, reddish, or reddish-brown, gray or grayish-black; that of Naples is generally gray; that of Civita Vecchia is more generally reddish, or reddish-brown. The red variety is the proper puzzolana; the black and the white sorts are called, in Italy, *lapillo*, or *rapillo*. The ashes which overwhelmed Pompeii now form an immense bed of white

puzzolana. The surface of this substance is rough, uneven, and of a baked appearance. It comes to us in pieces, from the size of a nut to that of an egg. It is wholly destitute of internal lustre and transparency. It is easily frangible, and its fracture is uneven or earthy, and porous; commonly filled with particles of pumice, quartz, scoriæ, &c. Hardness, 3. Very brittle. Specific gravity from 2.570, which is that of the black, to 2.785, rarely 2.8. Its smell is earthy. It is not diffusible in cold-water; but in boiling-water it gradually deposits a fine earth. It does not effervesce with acids. Heated, it assumes a darker colour, and easily melts into a black slag, or, with borax, into a yellowish-green glass. Before it is heated, it is magnetic, but not afterwards. By Mr. Bergman's analysis, it contains from 55 to 60 per cent. of siliceous earth, 19 to 20 of argillaceous earth, 5 or 6 of calcareous earth, and from 15 to 20 of iron. When mixed with a small proportion of lime, it quickly hardens; and this induration takes place even under water. This singular property proceeds, as Mr. Kirwan supposes, from the magnetic state of the iron it contains; for this iron, being unoxygenated, subtilly divided, and dispersed through the whole mass, and thus offering a large surface, quickly decomposes the water with which it is mixed, when made into mortar, and forms a hard substance, analogous to the specular iron-ore, as it does in the iron tubes, in which water is decomposed, in the experiments of M. Lavoisier and Dr. Priestly; for in these the iron swells and increases in bulk; and so does puzzolana, when formed into mortar, as we learn from Higgins *on Cements*. One principal use of lime seems to be to heat the water, as, while it is hot, it cannot pervade the caked argil that invests the ferruginous particles; yet, in time, even cold water may pervade it, and produce hardness; and hence, as M. Dolomieu has observed, lavas become harder when moistened. If the mortar be long exposed to the atmosphere, fixed air, as well as pure air, will unite to the iron, rust will be produced, and the mortar will not then harden, as Dr. Higgins has noticed. Clay, over which lava has flowed, is frequently converted into puzzolana; but volcanic scoriæ never afford it; either because they are much calcined, or retain sulphur, or its acid. The ancients were well acquainted with this substance and its properties: and, among them, its principal use, as it has been also in modern times, was that of mixing it with their cements for buildings sunk into the sea. As it hardens and petrifies in water, it is of particular service in making moles and other buildings in maritime places.

PYCNOSTYLE, (from πυκνοστυλος, formed from πυκνος, *close*, and στυλος, *column*,)in the ancient architecture, a building where the columns stand very close to each other; one diameter and a half of the column being allowed for the intercolumniation.

The pycnostyle is the smallest of all the intercolumniations mentioned by Vitruvius. Some make it the same with *systyle*; others distinguish the latter by its allowing half a module more in the Corinthian intercolumniation.

The pycnostyle, Mr. Evelyn observes, chiefly belonged to the Composite order, and was used before the most magnificent buildings; as, at present, in the peristyle of St. Peter's at Rome, consisting of nearly three hundred columns; and such as yet remain of the ancients among the lately-discovered ruins of Palmyra.

PYRAMID, (from the Greek, πυραμις—derived from πυρ, fire) a solid standing on a square, triangular, or polygonal basis, and terminating at top in a point; or a body whose base is a regular rectilinear figure, and whose sides are plain triangles; their several verticals meeting together in one point.

Euclid defines it a solid figure, consisting of several triangles, whose bases are all in the same plane, and have one common vertex.

The pyramid is said to be *triangular*, *quadrangular* *quinquangular*, &c., according as the base is triangular. quadrangular, &c. The pyramid may be called a square, triangular, &c. cone; or the cone may be denominated a round pyramid. When very narrow at bottom, i. e. their base very small, they are called *obelisks* and *needles*.

Some derive the word from πυρος, *wheat*, and αμαω, *colligo*; pretending that the first pyramids were built by the patriarch Joseph, for granaries. But Villalpandus and Bryant, with much better reason, derive the word from πυρ, *fire*; because of their ending in a point like flame; whence the latter writer conceives them to have been originally altars dedicated to the sun.

Wilkins, conversant with the Coptic tongue, suggests another derivation from that language, in which *pouro* signifies a king, and *miri*, a race or generation; and he says, the pyramids were thus called, because they were erected to preserve the memories of the Egyptian kings and their families; and that those who descended from them had recourse to these pillars in order to prove their pedigree: but this supposition can have very little weight, when it is recollected that the memory of the founder of the largest of the Egyptian pyramids was lost long before the days of Herodotus. And as to their having been erected for granaries, their internal capacity is so limited, that the nation could have derived no just benefit from them. We therefore prefer the idea of Villalpandus and Bryant as to the derivation of the term.

Pyramids are now, sometimes, erected to preserve the memory of singular events, or to transmit to posterity the glory and magnificence of princes; but, as they are the symbols of immortality, they are more commonly used as funeral monuments. Such is that of Cestius at Rome, the mausoleum of that distinguished Roman, who was one of the seven officers called *Epulones*, and is said to have lived under Augustus; it was repaired in 1673 by Pope Alexander VII.

The pyramids of Egypt, comprehending the great and small, are very numerous; of these there are about twenty of the largest size. The most remarkable are the three pyramids of Memphis, or, as they are now called, of Gheisa, Geeza, or Gizé. The dimensions of the greatest of these have been differently stated both by ancient and modern writers. Herodotus (lib. ii.) makes the base of it to be 800 Grecian feet long; Diodorus (lib. i.) 700; Strabo (lib. xvii.) less than 600; and Pliny (lib. xxvi. c. 12.) 883 feet. Among the moderns, Sandys found it to be 300 paces; Bellonius, 324; Greaves, 693 English feet; Le Bruyn, 704 French feet, or 750 English feet; Prosper Alpinus, 750 French feet; Thevenot, 682; Niebuhr, 710; Chazelles, 704.80 English feet. In order to reconcile these differences, Dr Shaw observes that none of the sides of this pyramid are exactly upon a level; so that it is difficult to find a true horizontal base; besides, it is impossible to say how much the drifts of sand, to which it is exposed, may have been accumulated above the foundation of it; and, therefore, all calculations depending upon the time and circumstances of the situation, when they were made, must be exceedingly precarious. The perpendicular altitude of it, according to Greaves, is 499 feet; but its oblique height is equal to the breadth of the base, or 693 feet. The whole area of the base contains 480,249 square feet, or $11\frac{1989}{43500}$ English acres. The height, according to Herodotus, is 800 French feet; according to Strabo, 625; according to Diodorus Siculus, 600 and a fraction; as stated by Le Bruyn, 616; by Prosper Alpinus, 625; by Thevenot, 520; by Niebuhr, 440. The ascent to the top of

this pyramid is by steps, the lowermost being nearly four feet high and three broad; the second, of the same dimensions, but retiring inward from the first about three feet; and in the same manner the third row is placed upon the second, and the rest in the same order, to the top, which terminates in a small flat or square; and they are so disposed, that a line stretched from the bottom to the top would touch the angle of every step. These steps are called by Herodotus little altars, on account of their form; and their number has been variously assigned: Greaves states them at 207; Maillet at 208; Pococke at 212; Belon at 250; Thevenot at 208, and Chazelles at 498.222 English feet.

This pyramid is situate on a rocky hill, in the sandy desert of Libya, about a quarter of a mile from the plains of Egypt, above which the rock rises 100 feet or more, with a gentle and easy ascent. Upon this advantageous elevation, and solid basis, the pyramid is erected: the height of situation adding to the beauty of the work, and the solidity of the rock affording it a stable support.

We may here observe, that the sides of this pyramid stand exactly facing the four cardinal points, and consequently mark the true meridian of the place: which precise position could not have been well owing to chance, but was, probably, the effect of design and art. We may hence infer that the Egyptians had made an early progress in astronomy.

The entrance is nearly in the centre, and a passage descending at an angle of 27° terminates in an unfinished chamber, below the level of the ground. About 100 feet from the entrance, this passage is joined by an upper one, which ascends at the same angle to the great gallery, where it runs horizontally into what is now called the Queen's Chamber. But the gallery itself, continuing at an angle of 27°, leads to a larger room, called the King's Chamber, in which is a sarcophagus of red granite, 7 feet 4 inches by 3 feet, being only 3 inches less than the width of the door by which it was admitted. At the bottom of the great gallery is the well; and it was by this that the workmen descended, after they had closed the lower end of the upper passage, which was done with blocks of granite. And having gone down by the well, and reached the lower passage, they followed it upwards to the mouth, which they also closed.

Several other chambers and passages, hitherto undiscovered, no doubt exist in the upper part of the pyramid, and one seems to be connected with the summit of the great gallery. It appears to run upwards in a contrary direction to the north, from that end which is above the well; where a block, apparently of granite, projects at the complement of the usual angle of these passages. It probably turns afterwards, and extends in a southerly direction over the great gallery. Above what is called the King's Chamber, is a low room, which should support another similar chamber, and the stone at the south-west corner of it, has probably been let in after the workmen had closed the above-mentioned passage; so that this room served also as an outlet from the upper apartments, as the well from those about the great gallery.

The second pyramid stands at about a bow-shot from the first, towards the south. Herodotus says, after having measured both, that it falls short of the other in magnitude; that it has no subterraneous chambers, and that the Nile is not conveyed into it by a channel, as into the former, but that it is of equal altitude. Diodorus says it resembles the first in architecture, but is inferior in magnitude; each side of the base containing a stadium, or 600 Grecian feet, in length, so that by his computation each side is less than that of the former in length by 100 feet. Pliny makes the difference to be greater by 46 feet. Thevenot makes it but 631 feet square. Strabo supposes these pyramids to be equal; and Greaves assures us, that the basis of both are alike, and that the height of the second is not inferior to that of the first. This pyramid is built of white stones, not near so large as those of the first: the sides do not rise with gradations, but are smooth and equal, and the whole fabric, except on the south side, is quite entire. On the North and West sides of this second pyramid are two very stately and elaborate pieces of architecture, about 33 feet in depth, and about 1,400 in length, cut out of the rock in a perpendicular direction, and squared by a chisel; supposed to be designed for the lodgings of the Egyptian priests. The entrance to the interior is on the north front.

The first passage is built of granite, the rest are cut out of the natural sandstone rock, which rises above the level of the basis of the pyramid. This passage is 104 feet long, 4 feet high, and 3 feet 6 inches wide; descending at an angle of 26°, at the bottom is a portcullis, beyond which is a horizontal passage of the same height as the first, and at the distance of 22 feet, it descends in a different direction, leading to some passages below. Hence it re-ascends towards the centre of the pyramid, by a gallery 84 feet long, 6 feet high and 3.6 feet wide, leading to a chamber also cut out of the solid rock. The chamber is 46 feet in length, 16 feet wide, and 23.6 feet high, and contained a sarcophagus of granite, 8 feet long, 3.6 feet wide, and 2.3 feet deep in the inside. Returning from the chamber to the bottom of the gallery, a passage descends at an angle of 26° to the extent of 48.6 feet, when it takes a horizontal direction for a length of 55 feet; it then ascends at the same angle, and proceeds to the base of the pyramid, where another entrance is formed from the outside.

About the middle of the horizontal passage, there is a descent into another chamber, which is 32 feet long, 10 feet wide, and 8 feet 6 inches high.

The third pyramid stands at about the distance of a furlong from the second, on an advantageous rising of the rock, so that at a distance it appears equal to the former, though it is really much less and lower. Herodotus says it is 300 feet on every side, and to the middle, built of Ethiopic marble. Diodorus gives the same dimensions of its base, and adds, that the walls were raised fifteen stories with black stone, like Thebaic marble, and the rest finished with such materials as the other pyramids are built with; that this piece of work, though exceeded by the two former in magnitude, yet far excels them in respect to the structure, art, and magnificence of the marble; and that on the side towards the north, the name of Mycerinus, the founder, is engraved; but this inscription has been defaced by time. Pliny writes to the same effect, except that he makes this pyramid 363 feet between the angles.

Dr. Shaw apprehends, that neither of these pyramids was ever finished, supposing that the steps already mentioned should have been filled up with prismatical stones, so that each side of the pyramid might be smooth and level, like that of Cestius at Rome.

But, from the description of Maillet and Savary, the first pyramid appears to have been covered with a coating of marble, and thus finished on the outside, but closed; and that it has been since forcibly opened; and the stones which shut the passage, and were of an enormous size, have been removed. This passage was composed of marble, and the stones which form its four sides are of the finest white and hardest marble.

The ancients inform us, that the stones of the pyramids were brought from the mountains of Arabia; and Herodotus (lib. ii. c. '24.) has described the manner in which they were conveyed but Dr. Shaw imagines, that they were taken

from the spot where they were employed; and he observes, that the greatest of them, especially, is not an entire heap of hewn stones, because that portion of it which lies below the horizontal section of the entrance, may probably be no more than an incrustation of the natural rock on which it is founded. Mr. Bryant conjectures that, like the sphynx, which stands directly in the front of the second pyramid, they were immense rocks which stood upon the brow of the mountain; that the Egyptians cased them over with large stones, and brought them, by these means, to a degree of symmetry and proportion. At the same time, they filled up the unnecessary interstices with rubbish and mortar, and made chambers and apartments, as the intervals in the rock allowed, being obliged to humour the indirect turns and openings in the original mass, to execute what they proposed. This he infers from the narrowness and unnecessary sloping of the passages, which are often very close and steep, and also from the fewness of the rooms in a work of so immense a structure. That the pyramids were built upon a rock, in the place where they now stand, was suggested by Mr. Hooke.

The pyramids of Saccara, which are as many as 20 in number, vary in form, dimensions, and construction. They extend five miles to the north and south of the village of Saccara. Some of them are rounded at the top, and resemble hillocks cased with stone. One is constructed with steps, like that of Cheops. They are six in number, each 25 feet high, and 11 feet wide. The height of one in the group is 150 feet. Another, built also in steps, is supposed to be as high as that of Cheops. The stones whereof they are composed are much decayed, and more crumbling than those of Gizeh, hence they are considered older. One of them is formed of unburnt bricks, containing shells, gravel, and chopped straw.

The general opinion, with regard to the intention and use of pyramids, is, that they were sepulchres and monuments of the dead, particularly of kings. This is expressly affirmed by Diodorus, (lib. i.) and Strabo (lib. xvii.); and the opinion is confirmed by the writings of the Arabians. And the reason, says Greaves, of their erecting these magnificent structures is founded on the theology of the Egyptians, who, as Servius shows, in his *Comment upon Virgil* (Æneid, lib. iii.) where he describes the funeral of Polydorus—*Animamque sepulchro condimus*—believed, that as long as the body endured, so long the soul continued with it; and this was also the opinion of the Stoics. The reason of their building their sepulchres in the form of pyramids, was either from a notion that this was the most permanent form of structure, or because they hereby intended to represent some of their gods; particularly, as Greaves conjectures, Osiris, or the sun with many rays; for, under this form, the statues of the gods were frequently exhibited, and the gods themselves worshipped.

Among the Egyptians, the pyramid is said to have been a symbol of human life; the beginning of which is represented by the base, and the end by the apex; on which account it was that they used to erect them on sepulchres.

The tomb of Porsenna, king of Etruria, at Clusium, in Italy, is an ancient monument of square stone, each side of which is 300 feet broad, and 50 feet high. Within the square base, says Pliny, quoting from Varro, there is an inextricable labyrinth; upon this square stand five pyramids, four in the angles, and one in the middle, 75 feet broad at the bottom, and 150 feet high, and terminating in a point; at top, they are covered with a brass circle, from which are suspended bells, which are put in motion by the wind, so that their sound may be heard at a great distance. Upon this circle are four other pyramids, each 100 feet high; above which, upon one plane, are five other pyramids.

Pyramids are found in various parts of the world; indeed, the form of structure seems to have been not uncommon. Pyramidal tombs are found in Abyssinia, and even in Mexico, and the same form is observable in the constructed temples and pagodas of India and China. *See* Egyptian and Mexican Architecture.

Pyramid, *Properties of the.* 1. All pyramids and cones standing on the same base, and having the same altitude, are demonstrated to be equal.

2. A triangular pyramid is the third part of a prism, standing on the same base, and of the same altitude.

3. Hence, since every multangular may be divided into triangulars, every pyramid is the third part of a prism, standing on the same basis, and of the same altitude.

4. If a pyramid be cut by a plane parallel to its base, the section will be similar to the base.

5. All pyramids, prisms, cylinders, &c., are in a ratio compounded of their bases and altitudes: the bases, therefore, being equal, they are in proportion to their altitudes; and the altitudes being equal, they are in proportion to their bases.

6. Similar pyramids, prisms, cylinders, cones, &c., are in a triplicate ratio of their homologous sides.

7. Equal pyramids, &c. reciprocate their bases and altitudes: i. e. the altitude of the one is to that of the other, as the base of one is to the base of the other.

8. A sphere is equal to a pyramid whose base is equal to the surface, and its height to the radius of the sphere.

Pyramid, *to measure the surface and solidity of a:* Find the solidity of a prism that has the same base and height with the given pyramid: divide this by three; and the quotient will be the solidity of the pyramid. Or, multiply the base by the perpendicular height; and one-third of the product will be the content.

The surface of a pyramid is obtained, by finding the areas of the base and of the lateral triangles. The sum of these is the area of the pyramid. The external surface of a right pyramid, standing on a regular polygonal base, is equal to the altitude of one of the triangles which compose it, multiplied by the circumference of the base of the pyramid.

Pyramid, *Frustum of a.* *See* Frustum.

Pyramid, *Truncated.* *See* Truncated.

PYRAMIDOID, a solid generated by the revolution of a pyramid about its base.

Q.

QUADRA, in building, any square border, or frame, encompassing a basso-relievo, panel, painting, or other work.

The word is also used, erroneously, for a frame or border, of any other form; as round, oval, or the like.

QUADRÆ, the fillets on either side of the scotia of the Ionic base. Also the plinth or lower member of the podium.

QUADRANGLE, (from the Latin *quadrantus*, quartered, and *angulus*, a corner) a quadrangular, or quadrilateral figure; or a figure which has four sides, or four angles.

To the class of quadrangles, or quadrangular figures, belong the square, parallelogram, trapezium, rhombus, and rhomboides.

A square, &c. is a regular quadrangle; a trapezium, an irregular one.

Quadrangular figures are not proper for fortifications; the flanks and flanked angles being too small.

QUADRANT, (from the Latin *quadrans*, a fourth part) an arc of a circle, containing 90 degrees, or one-fourth of the entire periphery.

Sometimes, also, the space, or area, included between this arc and two radii, drawn from the centre to each extremity thereof, is called a quadrant, or, more properly, *a quadrantal space;* as being a quarter of the entire circle.

QUADRATURE, (from the Latin, *quadratura*) literally, the finding of a square equal in area to any given figure; which was the method the ancients made use of, when they had in view the determination of the surface of any space; but the term, *quadrature*, has now a more indefinite signification; implying, in general, the determination of the area of a figure, without any reference to the geometrical exhibition of it, in a square or other rectilinear form.

QUADRELS, a kind of artificial stones, perfectly square; whence their name. They are made of a chalky, or whitish and pliable earth, &c., dried in the shade for at least two years.

They were formerly in great request among the Italian architects.

QUADRIFORES, folding-doors which are divided into two in the height, so making four flaps.

QUADRILATERAL, from the Latin, *quatuor*, four, and *latus*, a side) a figure whose perimeter consists of four right lines, making four angles; whence it is also called a quadrangular figure.

If the several angles be right, the figure is a rectangular quadrilateral. If oblique, an oblique-angular quadrilateral.

If the sides of a quadrilateral be equal, and the angles right, the figure is a square.

If the sides be equal, but the angles unequal, the figure is a rhombus.

If the angles be equal, and the sides unequal, the figure is a rectangle.

If only the opposite angles and sides be equal, the quadrilateral is a rhomboides.

If the opposite angles and sides be unequal, the quadrilateral is a trapezium.

If any side of a quadrilateral, inscribed in a circle, be produced out of the circle, the external angle will be equal to the opposite internal angle.

QUADRIPORTICUS, a quadrangle with porticos or ambulatories on each side.

QUARREL, a lozenge-shaped pane of glass; also a tile or other material of the same form; same as QUARRY.

QUARRY, (from the Irish, *carrig*, a stone mine, or place where stones are digged. The methods which are practised in searching for, and ascertaining the presence of different sorts of materials of this nature, are principally those of boring, by means of an auger or borer made for the purpose, into the earth, and digging into it in other ways. In searching for most sorts of mineral substances, coals, and some other matters, the use of the borer is constantly first had recourse to, and not that of sinking a shaft, however favourable the appearances of the place may be for the purpose, and the success of the undertaking. The ground is first tried by this means, and a certainty of success or failure gained, as well as that of the most proper situation for sinking the shaft, or making the opening, or pit, without much expense being incurred, in case of the former. In trying for ochres, marls, and other similar articles, the same implement is also in common use. But in raising and providing lime-stone, free-stone, flags, and slates, &c., in some cases, digging down into, and opening the ground, by spades and other tools, is the mode employed in the first instance, in consequence of such substances being obviously present in sufficient quantities to be wrought with advantage.

Lime-stone is a very general sort of stone, raised from quarries and pits, in many different parts of this country, as in Devonshire, Sussex, Kent, &c., towards the south, where it lies in vast beds, from which it is dug for use; in the more midland counties, as in Gloucestershire, Shropshire, Derbyshire, Staffordshire, and others, where it exists, and is employed to a still greater extent; but by far the most extensively in those farther to the north, as Lancashire, Westmoreland, Yorkshire, Cumberland, and some districts of Scotland. In many parts of the county of Lancaster, it is dug and raised from quarries, where it lies in a stratified manner at no great depth from the surface, being got up without much difficulty or trouble; while, in other places, it is forced from the solid rock with great labour and expense. This is likewise the case in many other districts. Wherever it is met with it is almost constantly a quarry material of great value, and affords much employment to labourers.

In the county of Kent, the banks of some of the large rivers are scooped out into stone quarries in a remarkable manner, some of them worn out and disused, others in the state of being wrought. It has been observed, that this is the nearest stone county into which water-carriage can penetrate from the metropolis; and that the original London was built, as well as the modern one chiefly paved, by materials from this district, such as the rag stone, and the large pebbles gathered on the sea-shores, before the Scottish granite came into use. In the neighbourhood of Maidstone, there are appearances of many abandoned and neglected quarries of this nature; but the most considerable, which were lately wrought in that vicinity, are those of Farleigh and Fant. In each of these, blocks of stones, of different kinds, and of every form and size, are met with, being separated by seams, and large irregular masses of earth of various qualities: among the rest, brick earth of the best quality. In some places, the stones

are buried several feet under these earthy materials: in others, the rock rises to the surface. After this, the quarrymen worm their way; following it with irregular windings, leaving behind them refuse in greater quantity than the useful materials which they raise.

The stony surfaces which are principally met with in them are of two very distinct kinds: the one hard and of a strong contexture, provincially denominated *rag or Kentish rag;* the other of a soft crumbly nature, provincially termed *hassock.* The quarrymen are in the practice of dividing the first sort into two kinds; what they call the *common-rag* and the *cork-stone*, the latter being their principal object in these immense works. It has, in its general appearance, much resemblance to the strong gray limestones which are found in different parts of this country; but when minutely examined by means of a glass, its fracture and contexture have the characters of the Devonshire marbles: except that the grain of this sort of stone is somewhat coarser. In colour, too, it differs from those marbles, having a greater resemblance to the Yorkshire limestones. It is used for different purposes; much of it is sent to the neighbourhood of London, where it is burnt into lime for the use of the sugar-bakers; who for some reason or other chiefly employ lime burnt from this material, or stone, instead of that from chalk. It is likewise made use of as a building material; and particularly in pedestals, for the posts of cattle-sheds, and other farm-offices. It is hewn with stone-masons' axes, working with tolerable freedom.

It is very durable, as some part of the basement of Westminster Abbey appears to have been built with the stone from these quarries. In this case, it seems to have been dressed smooth: and the surface still remains with little alteration; having withstood the attacks of time with great firmness; it being, even now, difficult to detect a loosened splinter in the work.

The common rag-stone comprehends all the different kinds which are met with in these quarries, except that of the above, and that which is of the hassocky nature; though the true unmixed rag is a distinct sort, having characters different from any of the others. In colour, it inclines more to the red, or liver colour, than that of the cork-stone, but otherwise resembles it considerably. Viewed with a glass, its grain is finer, and the fracture flint-like.

It has of late years come into very extensive use. Its constituents are—carbonate of lime, with a little magnesia, 92.6; earthy matter, 6.5; oxide of iron, 0.5; and carbonaceous matter, 0.4 = 100.

The hassocky-stone appears, to the naked eye, to be of a soft, white, sandy quality; and its fracture is the same; but under the glass, its grain is fine, its contexture uniform, and so thickly interspersed with small seed like granules, of a dark or black colour, as to give it a gray appearance; sometimes bearing evident impressions of shells. Its texture is loose and brittle, crumbling easily between the fingers into a coarse, sand-like powder. It will not burn into good lime, although it is almost wholly calcareous.

Its principal use is that of forming a loose friable sort of rubbly sub-soil, in some places, where it is admirably suited to the growth of saintfoin, and some other crops of the plant as well as of the fruit-tree kinds.

The quarries in several other counties contain stony materials of all these different kinds, which are wrought and applied to a variety of uses.

Quarries of marble are wrought in several districts in different parts of the country, and afford great advantages in various ways. In Sussex they have a marble, which, when cut into slabs, is used for ornamenting chimney-pieces, and other purposes. It is equal in quality and beauty to most sorts, when highly polished. For square building and paving, it is also a material scarcely to be excelled. By burning, it likewise affords a very valuable manure, equal, and by some thought superior, to chalk, being cheaper to those who are near the places from which it is dug. It is found the most perfect about Kirdford, at the depth of from ten to twenty feet under ground, in flakes nine or ten inches in thickness, and is called *Petworth marble.* It was much employed in building the cathedral at Canterbury; the pillars, monuments, vaults, pavement, &c., being formed of it; and the archbishop's chair is one entire piece of it. Marble is got in some of the counties in the middle of the island, as Derbyshire, Nottinghamshire, &c.

At Beacon-hill, near Newark, a blue stone for hearths is obtained, which approaches to marble, and is capable of burning into lime. And, in the county of Derby, much good marble is raised in different places.—In Lancashire there are quarries of fine black marble, besides stones which approach to, and take on the polish of marbles. In many of the western and northern parts of Yorkshire, marble of various kinds is found, some much resembling, and others superior, in closeness of texture and distinctness of colours, to that which is wrought in Derbyshire. Also a stone, which greatly resembles the marble of that county, and which is capable of receiving much such a polish, and is nearly of the same colour, mixture, and appearance.

In the county of Inverness, likewise, marble of the greatest variety of colours, and of the most beautiful shades, has been met with in Ben-Nevis; and inexhaustible quarries of it lie untouched in the islands which belong to it.

Besides, this sort of material exists in immense quantities in quarries in many other parts of the kingdom.

Chalk is a material which is raised from quarries and pits, mostly in the southern parts of the country, as in Sussex, Surrey, Kent, Essex, Berkshire, Hertfordshire, &c. It exists in vast ranges and tracts in most of these districts, whence it is dug up from quarries, at different depths, according to circumstances, exposed in sheds to dry when wet, and then converted into lime for various uses, by means of fire: or it is employed in its broken and powdery state, without undergoing the above processes, by merely digging it out of such places. In some parts, as in Kent, and the neighbouring districts, it is often dug and raised from considerable depths, from beds of very great thicknesses. And near Reading, in Berkshire, there is a stratum of this substance, which is thirty feet in thickness. It is there used and dug out for manure, and occasionally as a building material; for the latter of which purposes it is very durable. The remains of the abbey of Hurley, and of the ancient chapel, now the parish church, built wholly of chalk, in the reign of William the Conqueror, are still as fresh and sound as if they had been the works of the last century. Chalk, when once indurated by the air, has a remarkable property of resisting the action of the weather.

Granite is a stony substance which is found to exist in some of the southern parts of the country, as well as in those of the north, but it abounds much more in the latter.

In the western parts of Cornwall, it is in great plenty in the districts of Penwith and Kirrier, presenting itself in large slabs on all the rocky hills or tors, as well as in the waste moors and valleys, and appearing in detached spots, even in the shelvy slaty tracts. It is of different colours and textures, being adapted to a great variety of uses and purposes, as those of building, and being wrought into columnar masses, eight or ten feet in length, for supporters to sheds, out-houses, &c., and as gate-posts, and bridges over brooks,

rivulets, &c., as well as in the forming of rollers, and malting, salting, and pig-troughs. It is also an article of commerce to different parts. It is supposed to be exactly of the same nature with the original granite; and there are five sorts of it, which are distinguished by their colours, the white, the dusky or dove-coloured, the yellow, the red, and the black, most of which are charged with a brown and bright silvery matter.

The county of Inverness has a great deal of this sort of stone, and there are numerous quarries for raising and working it. The common granite abounds in all the different districts of it. In many places, the whole rocks are composed of this kind, which is uncommonly useful for all ordinary purposes. By natural fissures, which run in straight lines, and generally at right angles, it is formed into all-sized portions and shapes, having uniformly a plain surface; and, by means of cutters or transverse lines, these stones are easily quarried, and found in the greatest plenty everywhere. They are remarkably beautiful, being almost as smooth and regular as hewn stone, and, of course, well suited for various sorts of building-work. The best buildings of the county-town are of a dark kind of granite, which is very hard and durable, but which has few or no fissures. It is generally found in large blocks; and in many of these parts, there is no other material for building or adding ornament with. The manner of giving it the polish it admits of, at the quarries, is by means of small picks or pick-axes, which are, in fact, hammers with sharp points at each end, in the manner of those employed by millers in preparing their grinding-stones. It is a very heavy, compact stone. There is a mixed sort, denominated *peasy granite*, which consists of white, black, and gray spots, that sparkle beautifully in the sun, is very ornamental, and much used for different purposes, as stairs, doors, and windows. Though this is very solid, and almost without natural fissures, it splits very straight, by means of iron wedges, set in a line, and struck alternately with a hammer of great power.

A great deal of this kind of stone is imported into the metropolis, and other large towns, for paving the streets, &c. It is, on the whole, a very advantageous sort of quarry material in various parts of the kingdom.

Quarries of freestone are wrought in a great number of different places. In the more southern parts is found the Portland-stone, which is so famous and useful in building. A sort of this kind of stone, which much approaches to it in quality, is also met with in Cornwall. Some likewise exists in Devonshire and Gloucestershire. The Cotswold quarries, in the latter, afford freestone of an excellent quality, particularly those at Painswick, Lodbury, Lockhampton-hill, &c. It abounds more, however, in Cheshire, Lancashire, Westmoreland, Cumberland, and some of the still more northern districts. Several excellent quarries of freestone are carried on in the first of these, as those at Runcorn, Manley, &c., where much valuable stone of this nature is raised. The second county also affords equally valuable quarries in many different places, from which vast quantities of the stone are raised, and employed, or sent away to a distance. Those about Ormskirk, Up-Holland, and Wigan, as well as those on all the eastern side, are in general of a very good quality; and in the vicinity of Lancaster there are some excellent ones; that on the moor, or common, close to the town, is very extensive, and affords a freestone that admits of a fine polish. In this district, this sort of stone is met with, of a whitish-brown, yellowish and reddish cast, but the first is by much the most esteemed. In the eastern parts of Westmoreland, as about Hutton Roofe, and some other places, a good sort of freestone is dug up from pits and quarries formed for raising it. This sort of stone exists, and is quarried almost all over, the counties of Cumberland and Northumberland; and prevails occasionally in others, where it is wrought to advantage. A grit-stone, somewhat of this nature, is met with in some districts, as in Shropshire, &c., which is raised from quarries, and used as a building material. And a sandstone exists to considerable extent in others, as in Sussex, &c., that is sometimes dug up, and made use of for common buildings, &c. In Cheshire, on the hills near Macclesfield, about Kerridge, a sort of sandstone is met with, which is particularly well suited to the making of flags, and whetting tools, as well as sometimes to the forming of slates, for which it was formerly much employed. Near Pott-Shrigley, also, a fine sandstone is found, that admits of a good polish. The quarry has not, however, been wrought for some late years, as, from the extreme hardness of the stone, the expense of getting it is very considerable. There are several other quarries of excellent freestone wrought in the same neighbourhood.

There has been great abundance of freestone wrought, from time immemorial, in the low parts of the county of Perth, and quarries of a greater or smaller grained stone of this sort appear almost in every place, with the exception of the Carses. In the Lowlands, and near to the eastern sea, the pores and grain of it are coarser; but as the mountains are approached, the pores are less, and the grain finer, by which these stones admit of a smoother polish. The quarry of Tullyalan parish, called Long-annat, affords a stone of a very excellent quality. It is of a white colour, admits of a smooth polish, and resists the influence of the weather. Some of the principal houses in that part of the country, as well as some of the most magnificent public buildings in the capital of Edinburgh, as those of the Exchange, the University, and the Register-office, consist partly of this stone, and those found at hand. And farther, in some instances it has been carried to the continent. But the quarry of Kingoodie, in the Carse of Gowrie, is unquestionably the finest of this kind of any in the country. Astonishing blocks, in great numbers, are raised there, fifty feet in length, sixteen feet in breadth, and three feet in thickness. Such is the demand for this stone, both at home and abroad, that four vessels are employed in exporting it from this quarry.

Flag-stones and quarries for the working and preparing of all sorts of flags, are met with in all those situations where free-stone is found, and where it exists in rather thick strata, or layers, of some depth, which are capable of being separated by hammers, wedges, or other means. In many places in the southern parts of the island, the flags raised from such free-stone quarries are of an extremely good quality, being used in very large quantities for various purposes. Those of Cornwall and Devonshire also, in many cases, afford a good sort of flags. The sandstone quarries of Shropshire as, at Grinsell, near Shrewsbury, about Bridgenorth, and at Corndon-hill, near Bishop's-Castle, as well as in the Swinney mountain, &c., where alternate beds of fine white and red stone of this kind, of very superior quality and thickness, exist; that in the first of these situations, being twenty yards thick, affords flags likewise which are of a very useful nature. Freestone flags, too, of useful sorts, are met with in the quarries of some of the midland counties; and they abound much in many of the freestone quarries of Lancashire, Yorkshire, and some of the other more northern districts of the country.

The quarries of this kind become slate-stone, and furnish the white, gray, and brown slate, wherever the stone lies in thin layers, or strata, which are able to be raised and separated from each other with convenience and facility. They

exist in most of the above tracts, and are plentiful in some of them, especially those toward the north. The Lancashire and Yorkshire quarries, in many places, supply the white and gray sorts in great abundance, and of good qualities. Those of Westmoreland, Cumberland, and Northumberland also afford them, in many instances, of a valuable nature; and they are equally good in the still more northern districts. There are numerous quarries of different colours of them in Clydesdale, Perthshire, Argyleshire, and the county of Inverness, from which vast supplies are constantly raised for home and other use. This sort of slate has, however, mostly the disadvantages of being very porous, heavy, less durable, and of requiring more and stronger timber to support it than some other kinds; being only fit for exposed climates and situations.

The quarries of the lighter and thinner kinds of slate, of the blue, green, purple, and other colours, formed from other sorts of stone, only exist in some particular districts, as those of Wales, and the northern part of Lancashire, and the adjoining counties, and in a few places in Scotland. The slate quarries of the Welch districts supply several kinds and colours in large quantities, and of good qualities; but the dark and lighter purples are the most prevalent sorts in most of them. In Lancashire, the quarries of this kind are very numerous in the part to the north of the Sands, as about Gothwaite-common, Kirby-moor, Conistone-hills, and Tilberthwaitefells, &c., and from which very large supplies of the blue, green, and the dark purple sorts of slate are raised, and sent away for exportation, or consumed at home for different purposes. They are wrought, and the slate prepared, in somewhat different manners in different places. The Gothwaite quarries have the slate dug out from the side of the hill, and carried away. But in some on Kirby-moor, a level is driven through the ground from below, the metal being conveyed away by small four-wheeled waggons, on iron railways. Those about Conistone are mostly worked into the hills, and the metal raised and carried out from them. Some of the Tilberthwaite quarries are wrought by blasting the slate-stone, and collecting and carrying it out of them on slanting roads, in small carts, or trucks, constructed for the purpose, of levels being below the hills, but not nearly so low as the bottoms of the quarries. Others are wrought by draught roads from the bottoms of them. One man will raise eighteen or twenty hundred-weight of slate in one day where the metal rises well, but less in other cases. In some, it is dug out by one set of men, split by another, and formed into slates by a third; for which purposes, flat crow-bars, slate-knives, and axes are employed. The slate is divided and distinguished into three sorts, as firsts, seconds, and thirds, or London, country, and toms. In the first, or Gothwaite quarries, the slate has a darkish purple or black cast. In the Conistone quarries, it has a fine blue and green appearance, and is much thinner and lighter than the other sort. The Tilberthwaite slate, in some instances, splits very fine, thin, and light, but does not cover so far as those of the Gothwaite and Kirby quarries. In some quarries a sort of rent is paid per ton, on the slate which is raised; while in others, a certain rent only is paid for the liberty of the royalty, and not a tonnage duty. These rents, or duties, on the workers of these quarries, are probably higher than they will bear, and have enabled the Welsh slate-dealers to undersell those of this county.

Westmoreland and Cumberland, in some instances, afford good blue and green slates. In the latter, some of an excellent quality are obtained in the quarries of Borrowdale, and inferior sorts in some of the neighbouring mountains.

The county of Argyle, in Scotland, in some parts, abounds with slate-quarries, as the tracts about Esdale, from which five millions of slates have for some time been annually sold. Quarries of the same kind are also wrought in many other parts, with great benefit to the inhabitants.

Slate-quarries are found in many parts of the highlands of the county of Perth, but none in the low. The slates in some are of a purple colour, in others of an azure blue, and in a few, of a muddy, sandy, brown complexion along the cutters. It is well known where the different sorts are quarried. The veins of slate-rock seem to run from Drumlane, in the parish of Aberfoil, in a north-east direction, to Dunkeld; and may be traced beyond the limits of the county both ways. The azure coloured are the best metal, and rise of a greater size than any of the other kinds. Many of the buildings in different places are slated with this beautiful covering. Into the lower districts of the county, slates are imported from Esdale, and the other quarries on the west coast of the county of Argyle.

Quarries of gray slate exist in many different parts of the county of Inverness, in which the quality is very good, and well suited to the climate. In some places these slates are much preferred to blue ones, as the latter are more expensive in procuring, and though nailed on the roofs ever so firmly, are apt to be loosened by high winds, unless bedded in lime, which circumstance renders repairs difficult.

Quarry, (from the French, *quarré*, square; or, according to some, a corruption of the English term, *quarrel*) a pane, or piece of glass, cut in a losenge or diamond form.

Quarries, or quarrels of glass, are of two kinds; viz. square and long, each of which is of different sizes, expressed by the number of pieces which make a foot of glass; viz., 8ths, 10ths, 12ths, 15ths, 18ths, and 20ths; but all the sizes are cut to the same angle, the acute angle being 77° 19′ in the square quarries, and 67° 22′ in the long ones.

Quarry-Cart, a name commonly given to that sort of cart which is principally employed in the work of quarries, and which is generally of a low, compact, strong kind, in its nature, form and manner of construction, in order to sustain heavy weights, and receive them without difficulty, or the danger of being destroyed. Carts for this purpose should always be made of well-seasoned wood, well put together, with sufficient strength of timber in those parts where the main stress of the load is placed.

Quarry-Waggon, or Truck, a small carriage of the low truck kind, which is much employed in the business of quarries, especially those of the slate kinds, for the purpose of holding and conveying the rough materials, which have been blown from the large massy rocks, or separated in other ways, out of or from the quarries and pits in which they are situate and contained, to the places where they are to receive their different preparations and shapes.

It is formed and constructed on a frame somewhat similar to that of the common barrow, and mounted on two low light iron-wheels on the fore part, having two feet behind, projecting from the frame, bent something in the manner of the letter S, and of sufficient length to let it stand or rest in a horizontal position while it is in the act of being loaded. These feet are usually made of iron, but they may be formed of other materials. A sort of inclined plane is formed from the bottoms of the quarries or pits, up which it is forced, with great ease and facility, by the workmen, or small animals of the horse kind, after being filled with these sorts of heavy materials.

QUARRYING, the business of directing and conducting the nature and management of sinking the different kinds of quarries, pits, and shafts, as well as of the different sorts of

work which are necessary to be undertaken, carried on, and performed in the several different descriptions of them; such as those of separating, getting up, and preparing the various sorts of materials for use in the arts, or in other ways. It is a practice which requires considerable knowledge and experience, to be fully master of it in all its different bearings and intentions. *See* QUARRY, and QUARRYING SLATES AND STONES.

Almost every kind of quarrying-work requires a different kind of management, not only in the opening and sinking the quarries and pits in the ground at first, but afterwards in the methods and practices of working them, and getting up the various sorts of materials from them, as well as in the modes of preparing, trimming, and arranging them, after they have been raised. They are, however, mostly well known and familiar to the quarry-men and pit-men, who are usually engaged in works of the several kinds.

QUARRYING SLATES AND STONES, the methods of preparing them for their different uses and applications at the quarries and pits where they have been raised. The former of these articles, particularly those of the blue, green, and purple or blackish kinds, undergo several different sorts of preparation in the quarrying, according to the purposes to which they are to be afterwards applied. They are separated and divided into very thin pieces, or slates, where light neat coverings are required, or in much demand; but for more strong and heavy coverings, in exposed situations, or other places, they are split into much thicker sheets, layers, or slates, and are, of course, more clumsy in their appearance.

Each sort, in the business of quarrying, is wrought in a separate manner, and packed up by itself; the different sorts having appropriate names, as has been already seen.

The white or brown slates are never divided and prepared in so fine a way as the other kinds, but separated into much thicker flakes or laminæ, in this intention. The blue, green, and purple or darkish sorts, are, for the most part, found capable of being split into very thin laminæ, or sheets; but those of the white, or brownish freestone kinds, can seldom be separated or divided into any very thin slabs, as the layers of the large masses of the stones are of a much thicker nature, they consequently form heavy, strong, thick coverings, proper for buildings in exposed climates and situations, and of the more rough kinds, such as barns, stables, and other sorts of out-houses.

In the different operations and processes of this sort of quarrying, slate-knives, axes, bars, and wedges, are chiefly made use of for the different purposes of splitting and cleaning the slates, they being separated into proper thicknesses by the axe, bar, and wedge, and afterwards chipped into their proper forms and shapes by the knife. All the inequalities which may appear upon any of them, are removed by this last-named implement. In the quarrying of the latter sorts of materials, or those of stones, the work is usually performed in such a manner as to suit the different uses for which they are intended. Where flags are to be formed, they are split or riven into suitable thicknesses, and squared to different sizes, so as to be adapted to different applications. These operations are executed in rather a rough way, as they are afterwards to be finished by the stone-mason. When for steps, they have the proper breadths and depths given to them in a sort of squaring manner, being left to be completed as they may be wanted for particular uses and applications. Gate-posts are, for the most part, quarried so as to have from about a foot to a foot and a half or more in the square. Trough-stones have the quarrying performed so as to be formed into various proper-sized squares or other forms, in a rough manner, being left in these states to be afterwards hewn and hollowed out, in the intended parts, by the stone-masons.

Stones for building purposes are usually raised and quarried out roughly into something of the square shape, being left in that state for the builders, who afterwards fit them so as to suit their own purposes and intentions.

In the quarrying of stones, the quarrymen commonly make use of large hammers, with cutting ends on one side, the other being formed in a plain manner; strong, sharp, crow-bars, and broad, sharp, iron wedges; by which means these matters are, from the constant practice of the men, split and torn into such forms as are wanted, with great ease and facility.

QUARRYING TOOLS, the different sorts of implements made use of in the different works of the quarry. They are principally such as have been noticed in the former article; to which may be added different descriptions of picks, mattocks, and jumpers, or boring implements for the purpose of blasting the various kinds of stone, and other hard materials.

QUARRYINGS, the small pieces that are broken or chipped off from the different sorts of materials found and wrought in quarries while preparing for various uses. These substances where they are of the hard kind, such as those of the blue and lime stone, as well as some other sorts, are extremely well calculated for the purpose of forming and repairing roads, as they are nearly, if not quite, in a state fit for immediate application. Materials of these kinds ought, therefore, where they can be conveniently had, never to be neglected by those who have the care and management of roads, as they will save much expense and trouble, in a great number of instances.

QUARTERINGS, or QUARTERS, slight upright timber-posts framed together, and employed instead of walls for the separation of apartments &c.; they are lathed over in the same manner as ceilings, to receive plastering, but when used for external work they are usually boarded. They are of two kinds, single and double, the scantling of the former being 2 inches by 4 inches, and the latter 4 inches square; they are placed at about 12 or 14 inches apart. The term *quarterings* is especially applied to a series of quarters.

QUARTER-PARTITIONS, a partition composed of quarters.

QUARTER-ROUND, a term used by the workmen for any projecting moulding in general, whose contour is a perfect quadrant, or quarter of a circle, or which approaches near that figure. The architects usually call it *ovolo;* and Vitruvius, the *echinus;* but oval more properly applies to the quadrant of an ellipsis as used in Grecian architecture.

QUATRE-FOIL, (French, *quatre-feuille*), An ornament much used in Gothic architecture, formed by a moulding disposed in four segments of circles, forming four cusps or points at their intersection.

QUEEN-POST, a timber post employed in roofs, for the purpose of suspending the tie-beam. It performs the same office as a king-post, but the term is applied to such suspenders only when there is more than one in a single truss; when there is only one, it is termed a *king-post.*

QUICK-LIME, such lime as is in the caustic or most active state, and which possesses the greatest power of operating upon different substances with which it may come in contact. It is quite the opposite, in its qualities and properties, to that which has fallen down into a powdery state, in consequence of being saturated with water and carbonic acid gas, or fixed air, or which is slaked and become effete.

According to Dr. Anderson, lime is in the best and most fit state for the purpose of cement, when most perfectly caustic, or in the most crystallizing condition. It is remarked, that the powder of lime, when reduced by means of water into a fluid, or thin paste-like form, and then suffered to become

dry, concretes into a coherent mass, which fixes to stones and other rough bodies in a very firm manner, and in this way becomes a proper cement for building any sort of walls. And that, after this pasty material has once become firmly dry, it is quite indissoluble in water, and incapable of ever being softened again by the moisture of the atmosphere or other similar causes. Hence it excels many other sorts of cements.

When composed for the purpose of building walls, &c.; it is usually denominated *mortar;* but when formed as an application in the way of a smooth coating upon any plain surface without intermixture with stony matters, it is commonly termed *plaster.*

When made from the lime of the purer sort of lime-stone, it is found to be more soft and crumbly, and to acquire a less degree of hardness, and to be broken with much less force, than where the lime-stone, from which it is made, contains a large proportion of sand; in which case it becomes much more hard, firm and durable.

It has, however, been discovered, that the purest lime may be rendered a firm cement by adding a proper proportion of clean hard sand to it; hence the practice of blending sand with lime, when intended for mortar, has become so universal. This is fully shown to have been very early the case, by the oldest lime-built walls which are now to be met with.

It nevertheless still remains a desideratum to ascertain the due proportion of sand necessary, as both writers and practical masons greatly disagree in opinion on this matter, as well as in their directions about the mode of mixing the materials, and of applying the cement; some of the more modern, especially ascribing extraordinary effects to a small variation in these particulars, while others deny that these circumstances have any sensible effect on the durability and firmness of the cement.

It is conceived that these different and contradictory opinions arise from the imperfect knowledge of the nature of quick-lime, and the variations it may admit of; for these variations are so very great, as to render it impossible to afford any general rules that can possibly apply in all cases. It is, therefore, conceived to behove those who are desirous of acquiring any consistent and satisfactory knowledge on this head, to endeavour to ascertain, in the first place, the circumstances which render calcareous substances *at all* capable of becoming a cement, and then to trace the several changes that may be produced upon it by extraneous causes.

Having explained the circumstances which cause the differences in limestone, and pointed out the different constituent principles of it, as well as various other peculiarities; it is known, that lime which has in any way absorbed its full quantity of air from the atmosphere, and become mild, is altogether unfit for becoming a cement, and that, of course, a great change may be produced upon the quality of any lime, by having allowed less or more of it to be in this state before it is worked up into mortar. And farther, that if a large quantity of water be put to fresh-slaked quick-lime, and beat up with it into a thin sort of paste, the water dissolves a small portion of the lime, which, as it gradually absorbs its air, is converted into crystals; between the particles of which crystals, that part of the lime which was not dissolved, and the other extraneous matters which may have been mixed with it, are entangled, so as to form a firm coherent mass of the whole. And that the pasty substance formed in this manner, is the well-known article mortar; and this heterogeneous, imperfectly semi-crystallized mass, constitutes the common cement employed in building ordinary walls, or other erections. These circumstances, therefore, being known, it is thought that it will not be difficult to comprehend what are the particulars necessary to form the most perfect cement of this nature. That since lime becomes a cement only in consequence of a certain degree of crystallization taking place in the whole mass, it is sufficiently obvious that the firmness and perfection of that cement must depend upon the perfection of the crystals, and the hardness of the matters that are entangled among them; for if the crystals are ever so perfect and hard of themselves, if they be separated from each other by any brittle incoherent medium, it is evident that the whole mass must remain in some degree brittle and incoherent. That as water can only dissolve a very small proportion of lime, even when in its most perfect saline or caustic state, or while it remains deprived of its carbonic acid gas, and, as happens in other similar cases, no more of the lime can be reduced to a crystalline mass than has been actually dissolved in the water; it follows, of course, that if mortar be made of pure lime and water alone, a very small proportion only can be dissolved by that small quantity of water that is added to it; and as this small proportion alone can afterwards be crystallized, all the remaining undissolved particles of the lime will be entangled among the few crystals that are formed. And as the undissolved lime in this mass will in time absorb its air, and be converted into *mild* calcareous earth, without having had a sufficiency of water to allow it to crystallize, it must concrete into a friable mass, exactly resembling chalk; this kind of mortar, therefore, when as dry as it can be made, and in its highest degree of perfection, will always be soft, and easily crumbled into powder. But if, instead of forming the mortar of pure lime alone, a large proportion of sand be added to it, the water will, in this case, dissolve as much of the lime as in the former; and the particles of hard sand, like sticks or threads, when making sugar-candy or other crystals, while surrounded by the watery solution, will help to forward the crystallization, and render it more perfect than it otherwise would have been, so as firmly to cement the particles of sand to each other. And as the granules of sand are perfectly hard of themselves, so as not to admit of being broken down like the particles of chalk, it necessarily follows, that the cement made of these materials must be much more perfect, in every respect, than the former.

After considering a variety of circumstances in regard to the solubility of lime in water, and its crystallization, it is remarked, that when a large quantity of sand is mixed in the mortar, that sand will of course bear a great proportion to the whole mass; so that the water that may be mixed with the mortar will be much greater in proportion to the quantity of lime contained in this mortar, than if the whole had consisted of pure calcareous matter. And that, as the sand absorbs none of that water, the water, now pure, is at liberty to act once more upon those few particles of caustic lime that may still remain in the mortar, which will be dissolved and converted into crystals in their turn. In this way, it may happen, in some circumstances, that a very large proportion of the lime may become crystallized; so that the mortar will consist almost entirely of sand enveloped in crystalline matter, and become in due time as hard as stone itself; whereas mortar, consisting of pure lime, without sand, can hardly ever be much harder than chalk. It is not, however, to be supposed, that in any case this dried mortar will assume that transparent crystalline form, or the compact firmness of some sorts of calcareous matters, such as marble and limestone. In mortar, in spite of the utmost care that can ever be taken, a very considerable quantity of the lime must remain undissolved; which undissolved lime, although it may be so much separated by the sand and crystalline limestone as not much

to affect the hardness of the mortar, yet it must still retain its white chalk-like appearance. As marble and limestone are, however, always formed by those particles of lime that have been wholly dissolved in water, and from which they have been gradually separated by a more slow and more perfect mode of crystallization, they have nothing of that opaque calx-like appearance, but assume other colours, and appear more firm, uniform, and compact; the sand and other matters that may be enveloped in them being entirely surrounded with a pure crystalline matter.

But to obtain the most perfect kind of mortar, it is not, however, enough that a large proportion of sand should be employed, and that the sand should be intimately mixed with the lime; it is also of the utmost importance that a large proportion of water be added; for, without this, it is impossible that a large proportion of the lime can be crystallized: and the mortar, in that case, would consist only of a mixture of chalky matter and sand, which could hardly be made to unite at all, and would be little more coherent than sand by itself, and less so than pure chalk. In that case, pure lime alone must afford rather a firmer cement than lime with sand. It is also of very great importance that the water be retained as long in the mortar as possible: for if it be suddenly evaporated, it will not only be prevented from acting a second time upon the lime, after a part of what was first dissolved has been crystallized, but even the few crystals that would be formed when the water was suddenly evaporating, would be of themselves much more imperfect than they otherwise most certainly would have been. In proof of which, instances of the crystallization of common salt, lump-sugar, and sugar-candy, are adduced; after which it is noticed, that every one knows what a difference there is between the firmness of the different substances; and that as great must be the difference between the firmness of that cement which has been slowly dried, and that which has been hastily hardened by the powerful action of a warm air.

It is contended, that it is owing to this circumstance that the lime, which remains all winter in a mortar-tub filled with water, is always found to be much firmer and more coherent than the mortar that was taken from the same tub and used in any work of masonry, although in this case the materials were exactly the same. From the same cause, any work cemented with lime under water, if it has been allowed to remain undisturbed and uninjured until it has once become hard, is always much firmer than that which is above the surface of the water.

In order to render the force of the above reasoning more strong and convincing, lime-cement or mortar is compared to a mass of matter consisting of a congeries of stones closely compacted together, and united by a strong cementing matter, that had, while in a fluid state, pervaded all the interstices between the stones, and afterwards become a solid indissoluble substance. If the cementing matter be exceedingly hard and coherent, and if the stones bedded among it be also very hard and firm, the whole mass will become like a solid rock, without fissures, that can hardly be broken to pieces by the power of man. But, although the cement should be equally firm, if the stone, of which it consists, be of a soft and friable nature, suppose chalk or sand-stone, the whole mass will never be capable of attaining such a degree of firmness as in the former case; for, when any force is applied to break it in pieces, although the cement should keep its hold, the solid matter cemented by it would give way, and the whole would be easily broken to pieces. Whereas, in mortar, the sand that is added to it represents the stones of a solid matter, in the composition, the particles of which are united together by the lime which had been formerly dissolved, and now crystallized, which becomes an exceedingly solid and indissoluble concretion; and as the particles of sand are of themselves exceedingly hard, and the cement by which they are united equally so, it is plain that the whole concretion must be extremely firm, so as to require very great force to disunite any particle of it from the whole mass. But if, instead of employing sand, the only solid body that is entangled among the cementing matter should be chalk, (as in all cases where the mortar consists of pure lime alone,) or any other slightly coherent substance, let the cementing particles of that composition be ever so perfect, it is impossible that the whole can ever attain a great degree of firmness, as these chalky matters will be easily broken asunder.

It is remarked, in addition, that a variety of conjectures have been made about the nature of the lime-cement employed by the ancients. It has been thought that they possessed an art of making mortar which has been long since entirely lost; as the cement in the walls which have been built by them, appears to be, in many cases, much firmer than that which had been made in modern times. Yet, when the mortar of these old buildings is analyzed, it is found to consist of the same materials, and nearly in the same proportions, in which they are now made use of. And it is thought probable, that their only secret consisted in mixing the materials more perfectly than the rapidity or avarice of modern builders will permit; in employing their mortar in a much more fluid state than is done now; and in allowing it to dry more slowly, which the immoderate thickness of many of their walls would naturally produce, without any preconcerted design on their part. Tradition has even handed down to the present times the memory of the most essential of these particulars; as the lower class of people, in every part of the nation, at this moment, invariably suppose and believe that these old walls were composed of a mortar so very thin, as to admit of its being poured, like a fluid, between the stones, after they were laid in the wall: and the appearance of these old walls, when taken down, seems to favour this popular tradition. Nor is it doubted but that this may have been the case. The stones in the outer part of the wall, it is thought, were probably bedded in mortar, nearly as is practised at present; and the heart, after being packed well with irregular stones, might have the interstices between them entirely filled up with fluid mortar, which would insinuate itself into every cranny, and, in time, adhere as firmly as the stones themselves, or even more so, if the stones were of a sandy friable nature. And that, as these walls were usually of very great thickness, it might often happen, that the water in this mortar, by acting successively upon different particles of caustic lime, would at length be entirely absorbed by successive crystallizations, so as to become perfectly dry, without any evaporation at all; in which case, a very large proportion of the original lime must have been regularly crystallized in a slow and tolerably perfect manner, so as to attain a firmness little inferior to limestone, or marble itself.

It is supposed that, upon these principles, it is easy to account for the superior hardness of some old cements, when compared with that of modern times, in which a practice very different is usually followed, without having recourse to any wonderful *arcana* whatever.

There are likewise a few other circumstances that may influence the quality of common lime-mortar. If limestone be sufficiently calcined, it is deprived of all its moisture, and of all its carbonic acid gas, or fixed air. But experience shows, that limestone will fall to powder on the effusion of water upon it, when it is much less perfectly calcined, and

while it still retains almost the whole of its fixed air. And that, as masons have hardly any other rule for judging whether limestone be sufficiently calcined, except this single circumstance of its falling to a powder when water is poured upon it, it may thus easily be perceived, that the same lime may be more or less fitted for making good mortar, according to a circumstance that, in a great measure, eludes the observation of operative masons; for if it should happen that all the pieces of lime drawn from a kiln at one time were just sufficiently calcined to make it fall to a powder with water, and no more, that powder would be altogether unfit for making mortar of any kind. This is a case that can seldom happen; but as there are a great many intermediate degrees between that state and perfect calcination, it must often happen that the stone will approach nearer to one of these extremes at one time than at another; so that the mortar may be much more perfect at one time than at another, owing to a variation in this particular.

All those who have written on the subject of lime as a cement, have endeavoured to ascertain what is the due proportion of sand for making the most perfect cement. But a little attention to the matter will show, that all rules which could be prescribed as to this particular, must be so vague and uncertain as to be of little utility to the practical mason; as, besides the variation which may arise from a more or less perfect degree of calcination as above, it is a certain fact, that some kinds of limestone are much more pure, and contain a much smaller proportion of sand, than others do; some being found almost perfectly pure, while others contain eleven-twelfths of sand, and all the intermediate proportions of it. Therefore, it would be absurd to say that pure lime would require as small a proportion of sand, when made into mortar, as that which originally contained in itself a much larger proportion of sand than any writer has ever ventured to propose for being put into mortar.

Besides, there are variations caused by the different nature of the calcination in the several sorts of limestone; from which it may, upon the whole, be concluded, that about one-tenth of *pure* limestone is not enough calcined to admit of being made into mortar; and that of the most impure sorts of limestone, not above one-fourth part of the lime contained in it is so much calcined as to be in a caustic state.

The variation that is produced by these means, in regard to the proportion of sand that will be required to the lime in the one or the other case, is found to be so extremely great as hardly to be conceived. It is, however, stated, that the best mortar that has been seen made was formed of lime which had been found to contain eleven parts of sand to one of lime; to this there was added between twice and thrice its whole bulk of sand by measure, which may be allowed to have been at least three times its quantity *by weight*. Therefore, supposing that every particle of that lime had been so perfectly calcined as to be in a caustic state, there could not be less than forty-seven parts of sand to one of lime. As much may, however, be allowed for the uncaustic part of the lime as is desired, and the calculation made accordingly. But it is hardly possible to suppose that above one-hundredth part of this mass, independent of the water, consisted of pure caustic calcareous earth.

On these considerations it is conceived, that it is impossible to prescribe any determinate proportion of sand to lime, as that must vary according to the nature of the lime, and other incidental circumstances, which would form an infinity of exceptions to any general rule. But it would seem that it might be safely inferred, that the moderns, in general, rather err in giving too little sand than in giving too much. It deserves, however, to be noticed, that the sand, when naturally in the limestone, is more intimately blended with the lime than can possibly be ever effected by any mechanical operation; so that it would be in vain to hope to make good mortar artificially from pure lime, with such a small proportion of caustic calcareous matter as may sometimes be effected when the lime naturally contains a very large proportion of sand. But there seems to be no doubt, that if a much larger proportion of sand were employed, and if that were more carefully blended and expeditiously worked than is common the mortar would be much more perfect than is usual in modern times, as has been proved by actual trials.

Another circumstance that tends greatly to vary the quality of cement, and to make a greater or smaller proportion of sand necessary, is the mode of preparing lime before it is beaten up into mortar. When for plaster, it is of great importance to have every particle of the limestone slaked before it is worked up; for, as smoothness of the surface is the most material point, if any particles of lime should be beaten up in it, and employed in work before sufficiently fallen, the water still continuing to act on them after it was worked up, would infallibly slake such particles, which, forcibly expanding themselves, would produce those excrescences on the surface of the plaster commonly termed blisters. Consequently, in order to obtain a perfect kind of plaster, that will remain smooth on the surface, and free of blisters, there is an absolute necessity to allow the lime to lie for a considerable time macerating or *souring* in water, before it is worked up. And the same sort of process is necessary for the lime, when intended for use as mortar, though not so absolutely. Great care is, however, required in the management in this respect; the principal things being the getting of well-burnt lime, and the allowing it to macerate or *sour* with the water for only a *very short time* before it is used; but that which is the best burnt will require the maceration of some days in the water before it is sufficiently slaked in the whole mass for this purpose.

It has been almost universally admitted, that the hardest limestone affords a lime that will consolidate into the firmest cement; hence it is generally concluded, that lime made of chalk produces a much weaker cement than what is made of marble or limestone. It would seem, however, that if ever this be the case, it is only incidentally, and not necessarily so. As, from the nature of calcareous matter, every kind of lime is equally fit for becoming a firm cement, if it be first reduced to a proper degree of causticity, and has afterwards a due proportion of sand properly mixed with it, before it be employed in work. Different sorts of lime, without doubt, differ much from each other in the proportion of sand they naturally contain, and, of course, require very different proportions of sand to be added to them before they can be made equally perfect as a cement; which is an economical consideration of no small moment, in some cases, as it may make one sort of lime a great deal cheaper than another on some occasions, and, of course, deserves the attention of builders in general.

The excellencies and defects of other substances, that may be occasionally mixed with lime, in making cement, may be just noticed. Those commonly used as an addition to mortar, besides sand of various denominations, are powdered sandstone, brick-dust, and sea-shells. And, for forming plaster, where closeness rather than hardness is required, they use lime that has been slaked and kept long in a dry place till it has become nearly effete, powdered chalk, or whiting, and gypsum, in various proportions; besides hair and other materials of that nature. But some others have been more lately advised, such as earthy balls, slightly burnt and pounded, powdered and sifted old mortar rubbish, and others of a

similar kind. All of which substances are found objectionable, in some respect or other, for this use, sand being the only perfectly suitable material that can be easily met with; on which account, it has been always justly preferred. Pure firm crystallized sand is the best; though all pure sands are not equally proper for this purpose.

It is stated by Sir Humphrey Davy, in his work on *Agricultural Chemistry*, that there are two modes in which lime acts as a cement; in its combination with water, and in its combination with carbonic acid. When quick-lime is rapidly made into a paste with water, it soon loses its softness, and the water and the lime form together a solid coherent mass, which consists of seventeen parts of water, to fifty-five parts of lime. When this hydrate of lime, while it is consolidating, is mixed with red oxyde of iron, alumina, or silica, the mixture becomes harder and more coherent than when lime alone is used; and it appears, that this is owing to a certain degree of chemical attraction between hydrate of lime and these bodies: and they render it less liable to decompose by the action of the carbonic acid in the air, and less soluble in water. It is thought that the basis of all cements that are used for works which are to be covered with water must be formed from hydrate of lime; and that the lime made from impure lime-stones answers this purpose very well. Puzzolana, it is said, is composed principally of silica, alumina, and oxyde of iron; and it is used mixed with lime, to form cements intended to be employed under water. It is stated that Mr. Smeaton, in the construction of the Eddystone lighthouse, used a cement composed of equal parts, by weight, of slaked lime and puzzolana. Puzzolana, it is said, is a decomposed lava. Tarras, which was formerly imported in considerable quantities from Holland, is found to be a mere decomposed basalt: two parts of slaked lime and one part of tarras form the principal part of the mortar used in the great dykes of Holland. It is supposed that substances which will answer all the ends of puzzolana and tarras, are abundant in the British islands. An excellent red tarras may be procured in any quantities from the Giant's Causeway, in the north of Ireland: and decomposing basalt is abundant in many parts of Scotland, and in the north of England where coal is found.

It is observed that Parker's cement, and cements of the same kind, are mixtures of calcined ferruginous, siliceous, and aluminous matter, with hydrate of lime.

It is noticed, that the cements which act by combining with carbonic acid, or the common mortars, are made by mixing together slaked lime and sand. These mortars at first solidify as hydrates, and are slowly converted into carbonate of lime by the action of the carbonic acid of the air. It was found by Mr. Tennant, that a mortar of this kind, in three years and a quarter, had regained sixty-three per cent. of the quantity of carbonic acid gas, which constitutes the definite proportion in carbonate of lime. The hardness of the mortar in very old buildings is also thought to depend upon the perfect conversion of all its parts into carbonate of lime. The purest lime-stones are the best adapted, it is said, for making this kind of mortar. The magnesian lime-stones make excellent water-cements, but act with too little energy upon carbonic acid gas, to make good common mortar. The Romans, on Pliny's authority, made their best mortar a year before it was used; so that it was partially combined with carbonic acid gas before it was employed, it is supposed. See more on this subject under the articles Cement, Lime, Mortar, and Plastering.

QUIRE, the same as Choir.

QUIRK, a piece of ground taken out of any regular ground-plat, or floor. Thus, if the ground-plat were square, or oblong, and a piece be taken out of a corner, to make a court, or yard, &c., the piece is called a *quirk*.

Quirk-Mouldings are the convex parts of Grecian mouldings, where they recede at the top, and form a re-entrant angle with the soffit, or level surface which covers the moulding.

Quirks, in moulding, belong to the ovolo and semi-reversa.

QUOIN, or Coin, (from the French, *coin*, of the Latin, *cuneus*), a wedge. *See* Coin.

Quoins, (from the French *coin*, a corner), the corners of brick or stone walls. The word is particularly used for the stones in the corners of brick buildings. When these stand out beyond the brick-work (their edges being chamfered off) they are called *rustic quoins*.

R.

RAF

RABBET, or Rebate, *see* Rebate.

Rabbet-Plane, *see* Plane.

RABBETING, or Rebating, the planing or cutting of channels, or grooves, in boards.

RACK, the case in a stable where the hay is placed for the horses.

RADIUS, in a circle, the right line drawn from the centre to the circumference.

RAFTERS, (Dutch), pieces of timber, which, standing by pairs on the reason-piece, or raising-piece, meet in an angle at the top, and form the roof of a building.

It is a rule in architecture, that rafters should not stand farther than twelve inches asunder.

For the sizes or scantlings of rafters, it is advisable that *principal* rafters from 12 feet 6 inches, to 14 feet 6 inches long, be 5 inches broad at the top, 8 inches at the bottom, and 6 inches thick. Those from 14 feet 6 inches, to 18 feet 6 inches long, to be 9 inches broad at the foot, 7 inches at the top, and 7 inches thick. And those from 18 feet 6 inches, to 21 feet 6 inches, to be 10 inches broad at the foot, 8 inches at the top, and 8 inches thick. Single rafters, 6 feet 6 inches long, must be 4 feet 3 inches in their square.

RAI

Rafters, the inclined timbers disposed in the sides of a roof, so that their edges may be in planes parallel to the covering which is supported by them. See the article Roof, Curb roof; but more particularly Mechanical Carpentry.

RAG-STONE, a kind of limestone much used in building of late. *See* Quarry.

RAIL, (from the German, *riegel*), in *architecture*, is applied variously; particularly to those pieces of timber which lie horizontally between the panels of wainscot, and over and under them. The word is also applied to those pieces of timber which lie over and under balusters in balconies, staircases, &c. Also, to the pieces of timber that lie horizontally from post to post in fences, with pales or without.

RAILING, in *Rural Economy*, a sort of fence constructed with posts and rails. It is often made use of in protecting young hedge-fences from the cropping of cattle or other animals. Any sort of coarse timber does very well for this last purpose, such as outside planks, and the boughs or loppings of timber plantations.

RAILWAY, or TRAM-ROAD, or DRAM-ROAD, or WAGGONWAY, a track constructed of iron, stone, timber, or other material, upon the surface of an inclined plane, or other situation, for the purpose of diminishing friction, and thus serving for the easy conveyance of heavy loads of any kind of articles.

Railways were at first solely employed for transporting coals to a moderate distance from the pits, to the places where they could be shipped, and were universally made of wood. By degrees they were, however, carried to a farther extent; when the scarcity of wood, and the expense of their repairs, suggested the idea of employing iron for the purpose of improving these roads. At first, flat rods of bar-iron were nailed upon the original wooden rails, or, as they were technically called, *sleepers;* and this, though an expensive process, was found to be a great improvement.

They were next cast in the form of long narrow plates, with a vertical flanche on one side, so that the section presented the form of the letter L, and thus the wheels of the carriages were retained in the direction of the rails; the flanches on the wheels being dispensed with.

But the longitudinal timbers on which these plate-rails rested, being liable to rot and give way, were at last entirely discarded, and the rails were cast of sufficient depth to sustain the weight passing over them, and of length sufficient to reach from one cross sleeper to the next, to which they were secured by means of chairs; these rails were reduced in width, and the flanche transferred back again to the wheels.

About 1815, malleable bars were introduced, those of cast-iron having been found objectionable on account of their frangibility. The former were simply bars of iron, three or four feet long, and from one to two inches square, but they were found to destroy the wheels, on account of their narrowness: and a return to cast-iron appeared inevitable, until a new method of constructing the malleable rails was patented in 1820 by Mr. Birkinshaw. This improvement consisted in passing the bars, when red-hot, between rollers, which gave the required form to the rails, and by this means the bars were rolled in lengths of from 12 to 15 feet, and of any section required, the depth and breadth being increased in proportion to the distance from the bearings.

The rails are placed in chairs of cast-iron, which are spiked down to transverse timbers or sleepers, as they are termed, laid from 2 feet 6 inches to 3 feet apart. These sleepers are commonly of larch, about 9 feet in length, 9 inches in width, and 6 inches deep, and at either end at the distance apart of 4 feet 8½ inches, are placed the chairs or saddles to receive the ends of the rails, which run parallel to each other; they are generally about 5 inches deep at the centre, 2½ inches wide at the top and bottom, and ⅞ inch thick in the middle vertical rib.

The rails of the broad guage are placed 7 feet apart, and are spiked down to longitudinal timbers, which are kept equidistant by transverse sleepers.

The permanent way consists of a level roadway, properly ballasted with gravel or other suitable ballasting.

RAIN-WATER PIPE, a pipe fixed on the exterior of houses and other buildings, for the purpose of conveying rain-water from the roofs, &c., into a drain.

RAISER, a board set on edge under the foreside of a step, a stair, &c. *See* STAIRCASING.

RAISING-PIECES, or REASON-PIECES, in architecture, pieces that lie under the beams, and over the posts or puncheons.

The term is chiefly employed in buildings constructed of timber frame, where the interstices are filled with clay, or brickwork, called *panels*. In brick or stone buildings, the board or plank placed on the top of the wall is denominated the *wall-plate;* but, in some parts of the country, the wall-plates are denominated *platbands*.

RAKING, a term applied to such members of a building as slope or lie inclined to the horizon.

RAKING-MOULDING, in joinery, a moulding whose arrises are inclined to the horizon in any given angle.

If the raking-moulding has to meet with a horizontal moulding, at a given angle, on the plan; and if the section of the horizontal moulding be given; the following method will show how to find the section of the raking-moulding:

Figure 1.—Let the given moulding be a cima-recta; take any number of points in the curve, and through these points draw straight lines parallel to the rake; then the moulding shown in the middle of the rake, being pricked off from the level lines at the bottom, will give the section to work the raking-moulding.

If the moulding is required to be returned, as shown at the upper part, the inclined lines are continued; the proper projections are set at the top of the moulding, and vertical lines are drawn through the points of section to meet the respective inclined lines; then a curve, being drawn through the points of intersection, will give the horizontal return moulding at the top.

Figure 2.—An inclined cavetto, showing the section of the raking moulding, and also the section of the return level-moulding of the top.

Angle-bars, for shop-fronts, are also ranked among the class of raking mouldings. In *Figure* 3, let B be the common bar, of the same thickness with the angle-bar: take the raking projection, 1, 1, in C, and set the foot of the compasses in 1 at B, and cross the middle of the bar at the other 1; draw the lines 2, 2, 3, 3, &c. parallel to 1, 1, then prick the section at 1 C, from the ordinates so drawn at B, and thus the section of the angle-bar is obtained.

RAMMED-EARTH BUILDINGS, such as are raised with some sort of earthy material, hardened by being rammed into moulds or cases. This mode of building with earthy materials is supposed by some to have been known at a very early period, and has been long practised with success in the southern parts of France, especially about Lyons, though but little understood in any other part of Europe until comparatively lately. *See* PISE.

RAMP, in hand-railing, a concavity on the upper side, formed over risers, or over a half or quarter space, by a sudden rise of the steps above, which frequently occasions a knee above the ramp.

RAMPANT ARCH, one whose abutments spring from an inclined plane.

RAMPART, or RAMPIER, (from the Spanish, *amparo*, *defence*, or *covering*,) in fortification, a massy bank, or elevation of earth, about the body of a place, to cover it from the direct fire of the enemy, and of sufficient thickness to resist the efforts of the cannon for many days; and formed into bastions, curtains, &c.

Upon the rampart the soldiers continually keep guard, and pieces of artillery are planted there for the defence of the place. Hence, to shelter the guard from the enemy's shot, the outside of the rampart is built higher than the inside, *i. e.*

a parapet is raised upon it with a platform. Hence, also, earth not being capable to be raised perpendicularly, like stone, the rampart is built with a talus, or slope, both on the inner and outer side.

The rampart is sometimes lined, *i. e.* fortified with a stone wall withinside, otherwise it has a berme.

It is encompassed also with a moat, or ditch, out of which the earth that forms the rampart is dug.

The height of the rampart should not exceed three fathoms, this being sufficient to cover the houses from the battery of the cannon: neither ought its thickness to be above ten or twelve, unless more earth be taken out of the ditch than can be otherwise bestowed.

The ramparts of half-moons are the better for being low, that the small fire of the defendants may the better reach the bottom of the ditch; but yet they must be so high as not to be commanded by the covert-way.

RAMPART, in civil architecture, is also used for the space left void between the wall of a city and the nearest houses. This is what the Romans call *pomœrium*, in which it was forbid to build, and where they planted rows of trees, for the people to walk and amuse themselves under.

RAMPS, in fortification, gentle slopes made for the cannon to be drawn up and down by, and also for the easy communication of the troops posted in a battery raised above the level of the ground. The rise of these slopes is about two inches, on twelve of base; or the length of the base is six times the height, and this is general for the draught of carriages; but footways need not be of so gentle a slope, as a rise of one foot in three may answer the purpose; or, instead of ramps, stairs may be, and commonly are, used for the passage of the foot. The breadth of a carriage ramp is usually about nine or ten feet; but those for foot-passage only need not be above three or four feet wide. Ramps may either rise on the side of an elevated work, or against a salient angle of that work, or on each side of an entering angle.

RANGE, or RANGING, (from the French, *ranger*, to place in ranks,) a term applied to the edges of a number of bodies, placed in a given surface: thus, if the edges of the ribs of a groin were placed in a cylindric surface, they would be said to *range*. It is also used in speaking of the side of a work that runs straight, without breaking into angles.

RASP, a rough file.

RATE, in architecture, the particular class of a building, under which it is arranged, as to the quantity of ground on which it stands, its height, or destination.

This classification is only used in the neighbourhood of London, in order to modify the construction according to the regulations of the building act. *See* HOUSE.

RAVELIN, in fortification, was anciently a flat bastion, placed in the middle of a curtain; but now it is a detached work, composed only of two faces, which make a salient angle, sometimes without, and sometimes with flanks; and raised before the curtain on the counterscarp of the place; serving to cover it and the adjoining flanks from the direct fire of an enemy.

A ravelin is a triangular work, resembling the point of a bastion with the flanks cut off. Its use before a curtain is, to cover the opposite flanks of the two next bastions. It is used also to cover a bridge, or a gate, and is always placed without the moat.

What the engineers call a *ravelin*, the soldiers generally call a *demi-lune*, or *half moon*.

There are also *double* ravelins, which serve to defend each other. They are said to be double when they are joined by a curtain.

READING-DESK, a raised desk in churches, from which the lessons and other parts of the services are read. It is more correctly termed LETTERN, or LECTERN, and consists usually of one or two sloping-desks of sufficient size to sustain the books raised upon a pedestal or standard; they are mostly made of wood, but frequently of brass or other metal, and is enriched with various degrees of ornamentation. In many cases, the stem or pedestal was surmounted by an eagle with outspread wings, on which the books rested.

REBATE, or RABBET, (from the French, *rabbattre*, to abate,) a deep groove, or channel, cut longitudinally in a piece of timber, to receive the edge of a plank, or the ends of a number of planks, which are to be securely fastened into it. The depth of this channel is equal to the thickness of the plank, so that, when the end of the latter is let into the rebate, it will be level with the outside of the piece.

RECESS, (from the Latin, *recessus*,) a cavity in a wall, left either for ornament or use, or for both purposes united; for use, when it is to receive some piece of furniture, as a sideboard, or to add to the size of room; and for ornament when made in the form of a niche, to give beauty and variety to the building. When the construction of the edifice requires some of its walls to be of very great thickness, niches are frequently taken out of the wall, to lessen its thickness and give a greater quantity of floor-room; so that utility and ornament are united, and the expense of materials is saved.

RECIPIANGLE, or RECIPIENT-ANGLE, a mathematical instrument, serving to take the quantity of angles; used especially in the drawing of plans of fortifications.

The recipiangle was formerly a popular instrument among the French, but little known among us; it is usually very simple, in form of a square, or rather a *bevel*; consisting of two arms, or branches, riveted together, but moveable, like a sector, on the centre or rivet.

To take an angle with it, the centre of a protractor is laid to the joint, and the degrees cut by the edge show the quantity of the angle; otherwise the angle made by the two rulers is drawn on paper, and then measured with a protractor.

Sometimes there is a circle divided into degrees added over the centre or rivet, with an index to show the degrees without a protractor. At other times the under branch is divided.

To measure a salient angle with any of the recipiangles, apply the insides to the lines that form the angle; for a re-entering angle, apply the outsides, &c.

RECTANGLE, (from the Latin, *rectangulus*,) called also *oblong*, and *long square*, a quadrilateral rectangular figure, whose opposite sides are equal. Or, a rectangle is a parallelogram, whose angles are right.

RECTANGULAR, a term applied to figures and solids which have one or more angles right. Such are squares, rectangles, and rectangled triangles, among plain figures; cubes, parallelopipeds, &c. among solids.

Solids are also said to be rectangular with respect to their situation: thus, if a cone, cylinder, &c. be perpendicular to the plane of the horizon, it is called a rectangular or right cone, cylinder, &c.

The ancients used the phrase *rectangular section of a cone*, to denote a parabola, that conic section, before Apollonius, being only considered as a cone, whose section by the axis would be a triangle right-angled at the vertex.

Hence it was that Archimedes entitled his book of the quadrature of the parabola, by the name of *Rectanguli Coni Sectio*.

RECTANGULAR, or RIGHT-ANGLED TRIANGLE, a triangle, one of whose angles is right, or equal to 90 degrees. *See* TRIANGLE.

RECTIFICATION, in geometry, the finding of a right line equal to a proposed curve, or simply finding the length of a curve-line ; a problem which, even in the present advanced state of analysis, is attended, in many cases, with considerable difficulty ; and was, *in all*, totally beyond the reach of the ancient geometers, who were not able to assign the length of any curve-line whatever ; though they could, in a few instances, determine the area of a curvilinear space. The first rectification of a curve-line was effected by Mr. H. Neal, as we are informed by Dr. Wallis, at the conclusion of his *Treatise on the Cissoid*. This curve was the semi-cubical parabola, and Neal's rectification of it was published in July or August, 1657 ; and in 1659, the same was done by Van Haureat, in Holland.

It is, however, to the doctrine of fluxions and differential calculus that we owe the complete rectification of curve-lines, infinite terms, when they admit of it ; and in others, by means of infinite series, circular arcs, logarithms, &c.

RECTILINEAR, or RIGHT-LINED, a term applied to figures whose perimeter consists of right lines.

RECTORY, the official residence of a parish priest, usually in close proximity to the church.

REDANS (French) projections constructed at intervals in walls built on sloping or uneven ground, for the purpose of preserving the same height through its whole length.

REDOUBT, or REDOUBTE (from the Latin *reductus*) in fortification, a small square fort, without any defence but in front, used in trenches, lines of circumvallation, contravallation and approach ; as also for the lodging of corps de garde, and to defend passages. Redoubts are usually figures of three, four, five, or six sides, encompassed with a ditch, and a bank of earth, which consists of two parts called *rampart* and *parapet*. In marshy grounds, redoubts are often made of stone-work for the security of the neighbourhood ; their face consists of from ten to fifteen fathoms ; the ditch round them from eight to nine feet broad and deep : and their parapets, which are cut into embrasures and merlons, have the same thickness.

The inner sides of square redoubts are usually between the limits of twelve and thirty-two yards ; and when they are to be defended by musketry, the number of men necessary to the defence may be thus determined ; half the side squared, gives the number of troops ; and twice the square root of a given number of men, shows the length in yards of the side of a square redoubt proper to contain them.

REDUCTION of a Figure, Design, or Draught, the making a copy of it, either larger or smaller than the original, still preserving the [illegible]nd proportion.

The great use of the proportional compasses is in the reduction of figures, &c., whence they are also called *compasses of reduction*.

REFECTORY, a dining-hall or refreshment room. The term is especially applied to the dining-halls of monastic or other religious establishments.

REFLEX, or REFLECT, in painting, is understood of those places in a picture which [illegible]osed to be illuminated by a light reflected from some othe[illegible]dy represented in the same piece.

Or, reflexes may be defined thos[illegible]places which, beside the general light that illumines th[illegible]iece, receive some particular light from their situa[illegible]h respect to some more illumin[illegible]ted polished bo[illegible]ects part of the rays it receives [illegible]on them.

Reflexes are scarcely sensible, except in the shadowed parts. The management of the reflexes requires great accuracy and skill. All reflected light is supposed to carry with it part of the colour of the body which reflects it : so that those places which receive this light must have their colour mixed or tinged with that colour. But the same place may receive reflexes from different objects, differently coloured, and those, again, receive reflexes from others. The painter, therefore, must have a view to every circumstance of the colour, light, and position of each figure ; he must consider what effect each has on others, and pursue nature through all the variety of mixtures.

REGLET, or RIGLET, (from the French *reglette*), a flat narrow moulding, used chiefly in compartments and panels, to separate the parts, or members, from each other, and to form knots, frets, and other ornaments. The reglet, according to Daviler, differs from the *fillet* and *listel* in that it projects equally, like a ruler.

REGRATING, among masons, &c., taking off the outer surface of an old hewn stone, with the hammer and ripe, in order to whiten and make it look fresh again.

REGULA, a band below the tœnia in the Doric architrave.

REGULAR FIGURE, a figure that is both equilateral and equiangular; *i. e.*, whose sides, and consequently its angles, are all equal.

The equilateral triangle and square are regular figures. All other regular figures, consisting of more than four sides, are called regular *polygons*. Every regular figure may be inscribed in a circle.

REGULAR BODY, called also PLATONIC BODY, a solid terminated on all sides by regular and equal planes, and whose solid angles are all equal.

The regular bodies are five in number, viz., the *cube*, which consists of six equal squares ; the *tetrahedron*, or regular triangular pyramid, having four equal triangular faces ; the *octahedron*, having eight ; the *dodecahedron*, having twelve pentagonal faces ; and the *icosahedron*, having twenty triangular faces.

REGULAR ARCHITECTURE, such as has all its parts disposed in regular symmetry, or that has its parts disposed in counter-parts.

REINS OF A VAULT, *see* VAULT.

REJOINTING, the filling up of the joints of stones in old buildings, &c., when worn hollow by the course of time, or by weather. Rejointing is to be performed with the best mortar, as that of lime and cement ; sometimes also with plaster, as in the joints of vaults, &c.

RELATION, in architecture, between the several parts and members of an edifice, constitutes what is otherwise called *symmetry*.

RELIEVO, RELIEF, or EMBOSSMENT, a term applied to a figure which projects from the ground, or plane, on which it is formed, whether it be cut with the chisel, moulded, or cast. There are three kinds of relievo, viz. *alto*, *basso*, and *demi-relievo*.

Alto-relievo, *haut relief*, or *high relievo*, is when the figure is formed after nature, and projects as much as the life.

Basso-relievo, *bas relief*, or *low relievo*, is when the work is raised but a little from its ground, as in medals, and the frontispieces of buildings, particularly the histories, festoons, foliages, and other ornaments, in friezes. *See* BASSO-RELIEVO.

Demi-relievo is when one half of the figure rises from the plane, *i. e.*, when the body of a figure seems cut in two, and one-half is clapped on a ground. When, in a basso-relievo, some parts stand clear out, detached from the rest, the work is called a *demi-bosse*.

RELIEVO also denotes the sally, or projecture of any architectural ornament.

This, Daviler observes, is always to be proportioned to the magnitude of the building it adorns, and the distance at which it is to be viewed. If the work be insulate, and terminated on all sides, it is called a *figure in relievo*, or a *round embossment*. Such are statues, acroters, &c.

RELIEVO, in painting, denotes the degree of force, or boldness, by which a figure seems, at a due distance, to stand out from the ground of the painting, as if really embossed.

The relievo depends much on the depth of the shadow, and the strength of the light; or on the light of the different colours bordering on each other; and particularly on the difference of the colour of the figure from that of the ground.

When the light is well chosen, to make the nearest parts of figures advance; and well diffused on the masses, still diminishing insensibly, and terminating in a large spacious shadow, brought off insensibly; the relievo is said to be *bold*, and the claire obscure *well understood*.

RENAISSANCE, that style which arose in the arts in general, and also in architecture, by the attempt made to revive classic taste upon the decline of the Gothic system. This revival was commenced in Italy in the latter part of the fourteenth century, by Brunelleschi, and still further developed by his successors, amongst whom may be mentioned Alberti, Bramante, Michael Angelo Buonarotti, Palladio, &c. The Gothic style had never been fully developed, nor obtained a secure footing, in Italy; and hence the classic styles were revived without difficulty, and with greater success than in those countries where the Gothic had been fully established; and although even in Italy the latter style does not seem to have disappeared immediately—for we see in many buildings an admixture of the two—still the struggle for pre-eminence was not so great, or of so long continuance, as in other countries. In Italy, the classic principles were at once introduced in the constructive and essential parts of the building, and the Gothic only retained in matters of detail; whereas in other places the contrary practice occurred—that is to say, the change took place gradually by the introduction or substitution of classic details upon buildings essentially Gothic, until at last the classic predominated both in essentials and accessories. *See* ITALIAN and TUDOR ARCHITECTURE.

RELIQUARY, a casket of wood, metal, or stone, frequently enriched with precious stones, &c., for the purpose of preserving reliques.

RENDERING, in building, *see* PARGETING and PLASTERING.

REPAIRING of large walls, doors, ceilings, coverings, &c., belongs to the proprietor, or landlord: the tenant is only charged with small repairs, or glass windows, locks, &c., by the French called *locative* repairs.

REREDOS, the ornamental screen, or other decorative work, of whatever kind, employed to enrich the wall at the back of the altar.

RESERVOIR (French), a large pond or pen of water, artificially made, in order to retain and collect it for the use of canals, rivers, mills, &c.

In a building, the reservoir is a large bason, usually of wood, lined with lead, where water is kept to supply the occasions of the house. Large reservoirs are frequently constructed of cast-iron.

The reservoir is sometimes, also, a large bason of strong masonry, clayed or paved at the bottom, where the water is reserved to feed *jets d'eau*, or spouting fountains.

RESISTANCE, or RESISTING FORCE, any power that acts in opposition to another, so as to destroy or diminish its effect.

Of resistance there are several kinds, arising from the various natures and properties of the resisting bodies, and governed by various laws: as the resistance of solids, the resistance of fluids, the resistance of the air, &c.

RESISTANCE OF SOLIDS, the force with which the quiescent parts of solid bodies oppose the motion of others contiguous to them.

Of this there are two kinds. The first, where the resisting and resisted parts, *i. e.* the moving and quiescent bodies, are only contiguous, and do not cohere; i. e. where they constitute separate bodies or masses.

This is what M. Leibnitz calls *resistance of the surface*; but which is now more commonly denominated *friction*.

The second case of resistance is where the resisting and resisted parts are not only contiguous, but cohere; i. e. are parts of the same continued body or mass.

To which we may also add, the resistance which takes place between surfaces of solids, when completely in contact, though not forming one and the same body; or the resistance they offer to separation.

RESISTANCE OF THE FIBRES OF SOLID BODIES, *Theory of the*. To form an idea of this resistance or renitency of the parts, suppose a cylindrical body suspended vertically by one end. Here all its parts, being heavy, tend downwards, and endeavour to separate the two contiguous planes, where the body is the weakest; but all the parts resist this separation by the force with which they cohere, or are bound together. Here, then, are two opposite powers; viz., the weight of the cylinder, which tends to break it; and the force of cohesion of the parts, which resists the fracture. If the base of the cylinder be increased, without increasing its length, it is evident the resistance will be increased in the same ratio as the base; but the weight also increases in the same ratio: whence it is evident, that all cylinders of the same matter and length, whatever their bases may be, have an equal resistance, when vertically suspended.

But if the length of the cylinder be increased, without increasing its base, its weight is increased, while the resistance, or strength, remains the same: consequently, it is weakened by its additional length, and has a greater tendency to break.

Hence, to find the greatest length a cylinder of any matter may have to break with its own weight, it is only necessary to know what weight is just sufficient to break another cylinder of the same base and matter: for the length of the required cylinder must be such, that its weight may be equal to the weight of the first cylinder, together with the additional weight that was employed in producing the separation.

If one end of the cylinder were fixed horizontally into a wall, and the rest suspended thence, its weight and resistance would then act in a different manner; and if it be broke by the action of its weight, the rupture would be at the end fixed into the wall. A circle, or plane, contiguous to the wall, and parallel to the base, and consequently vertical, would be detached from the contiguous circle within the plane of the wall, and would descend. All the motion is performed on the lowest extremity of the diameter, which remains immovable, while the upper extremity describes a quadrant of a circle, and till the circle, which before was vertical, become horizontal, *i. e.* till the cylinder be entirely broken.

In the fracture of the cylinder, it is visible, two forces have acted, and the one has overcome the other: the weight of the cylinder, which arose from its whole mass, has overcome the resistance which arose from the largeness of the

base; and, as the centres of gravity are points in which all the forces, arising from the weight of the several parts of the same bodies, are conceived to be united, one may conceive the weight of the whole cylinder applied in the centre of gravity of its mass, *i. e.* in a point in the middle of its axis: and the resistance of the cylinder applied in the centre of gravity of its base *i. e.* in the centre of the base; it being the base which resists the fracture.

When the cylinder breaks by its own weight, all the motion is on an immovable extremity of a diameter of the base. This extremity, therefore, is the fixed point of a lever, whose two arms are the radius of the base, and half the axis; and, of consequence, the two opposite forces do not only act of themselves, and by their absolute force, but also by the relative force they derive from their distance with regard to the fixed point of the lever.

Hence it evidently follows, that a cylinder, *e. gr.* of copper, which, vertically suspended, will not break by its own weight, if less than four hundred and eighty fathoms long, will break with a less length in an horizontal situation; because the length, in this latter case, contributes two ways to the fracture; both as it makes it of such a weight, and as it is an arm of a lever to which the weight is applied. Hence, also, the smaller the base is, the less length or weight will suffice to break it; both because the resistance is really less, and because it acts by a less arm of a lever.

If two cylinders of the same matter, having their bases and lengths in the same proportion, be suspended horizontally; it is evident, that the greater has more weight than the lesser, both on account of its length, and of its base. But it has less resistance on account of its length, considered as a longer arm of a lever, and has only more resistance on account of its base; therefore it exceeds the lesser in its bulk and weight more than in resistance, and, consequently, it must break more easily.

Hence we see why, upon making models and machines in small, people are apt to be mistaken as to the resistance and strength of certain horizontal pieces, when they come to execute their designs in large, by observing the same proportion as in the small. Galileo's doctrine of resistance, therefore, is no idle speculation, but becomes applicable in architecture, and other arts.

The weight required to break a body placed horizontally, being always less than that required to break it in a vertical situation; and this weight being greater or less, according to the ratio of the two arms of the lever, the whole theory is always reducible to this: viz. to find what part of the absolute weight the relative weight is to be, supposing the figure of the body known; which indeed is necessary, because it is the figure that determines the two centres of gravity, or the two arms of the lever. For if the body, *e. gr.* were a cone, its centre of gravity would not be in the middle of its axis, as in the cylinder; and, if it were a semi-parabolical solid, neither would its centre of gravity be in the middle of its length or axis, nor the centre of gravity of its base in the middle of the axis of its base. But still, wheresoever these centres fall in the several figures, the two arms of the lever are estimated accordingly.

It may be here observed, that if the base, by which the body is fastened into the wall, be not circular, but, *e. gr.* parabolical, and the vertex of the parabola be at the top, the motion of the fracture will not be on an immovable point, but on a whole immovable line; which may be called the *axis of equilibrium;* and it is with regard to this, that the distances of the centres of gravity are to be determined.

Now, a body horizontally suspended, being supposed such as that the smallest addition of weight would break it, there is an equilibrium between its positive and relative weight; and, of consequence, those two opposite powers are to each other reciprocally as the arms of the lever to which they are applied. On the other hand, the resistance of a body is always equal to the greatest weight which it will sustain in a vertical situation without breaking, *i. e.* is equal to its absolute weight. Therefore, substituting the absolute weight for the resistance, it appears that the absolute weight of a body, suspended horizontally, is to its relative weight as the distance of the centre of gravity from the axis of equilibrium is to the distance of the centre of gravity of its base from the same axis.

The discovery of this important truth, at least an equivalent to it, and to which this is reducible, we owe to Galileo. From this fundamental proposition are easily deduced several consequences; as, for instance, that if the distance of the centre of gravity of the base from the axis of equilibrium be half the distance of the centre of gravity of the body, the relative weight will only be half the absolute weight; and that a cylinder of copper, horizontally suspended, whose length is double the diameter, will break, provided it weigh half what a cylinder of the same base, 4801 fathoms long, weighs.

On this theory of resistance, which we owe to Galileo, M. Mariotte made a very ingenious remark, which gave birth to a new system. Galileo supposes, that where the body breaks, all the fibres break at once; so that the body always resists with its whole absolute force, or with the whole force that all its fibres have in the place where it is to be broken. But M. Mariotte, finding that all bodies, even glass itself, bend before they break, shows that fibres are to be considered as so many little bent springs, which never exert their whole force till stretched to a certain point, and never break till entirely unbent. Hence, those nearest the axis of equilibrium, which is an immovable line, are stretched less than those farther off; and, of consequence, employ a less part of their force.

This consideration only takes place in the horizontal situation of the body; in the vertical, the fibres of the base all break at once; so that the absolute weight of the body must exceed the united resistance of all its fibres: a greater weight is therefore required here than in the horizontal situation; that is, a greater weight is required to overcome their united resistance than to overcome their several resistances one after another. The difference between the two situations arises hence, that in the horizontal there is an immoveable point, or line, as a centre of motion, which is not in the vertical.

Varignon has improved on the system of M. Mariotte, and shown, that to Galileo's system it adds the consideration of the centre of percussion. The comparison of the centres of gravity with the centres of percussion afford a fine view, and set the whole doctrine in a most agreeable light.

In each system, the base, by which the body breaks, moves on the axis of equilibrium, which is an immoveable line in the same base; but in the second, the fibres of this base are continually stretching more and more, and that in the same ratio as they recede farther and farther from the axis of equilibrium; and of consequence, are still exerting a greater and greater part of their whole force.

These unequal extensions, like all other forces, must have some common centre where they all meet, and, with regard to which, they make equal efforts on each side; and, as they are precisely in the same proportion as the velocities which the several points of a rod moved circularly would have to each other, the centre of extension of the base, by which the body breaks or tends to break, must be the same with the centre of percussion. Galileo's hypothesis, according to

which the fibres are supposed to stretch equally, and break all at once, corresponds to the case of a rod moving parallel to itself, where the centre of extension or percussion does not appear, as being confounded with the centre of gravity.

The base of fraction being a surface, whose particular nature determines its centre of percussion, it is necessary that this should be first known, to find on what point of the vertical axis of that base it is placed, and how far it is from the axis of equilibrium. Indeed, we know in the general, that it always acts with so much the more advantage as it is farther from it; because it acts by a longer arm of a lever; and, of consequence, it is the unequal consistency of the fibres in M. Mariotte's hypothesis which produces the centre of percussion; but this unequal resistance is greater or less, according as the centre of percussion is placed more or less high on the vertical axis of the base, in the different surfaces of the base of the fracture.

To express this unequal resistance, accompanied with all the variation it is capable of, regard must be had to the ratio between the distance of the centre of percussion from the axis of equilibrium, and the length of the vertical axis of the base; in which ratio, the first term, or the numerator, is always less than the second, or the denominator; so that the ratio is always a fraction less than unity; and the unequal resistance of the fibres in M. Mariotte's hypothesis is so much the greater, or, which amounts to the same, approaches so much nearer to the equal resistance in Galileo's hypothesis, as the two terms of the ratio are nearer to an equality.

Hence it follows, that the resistance of bodies in M. Mariotte's system is to that in Galileo's, as the least of the terms in the ratio is to the greatest. Hence, also, the resistance being less than what Galileo imagined, the relative weight must also be less; so that the proportion already mentioned, between the absolute and relative weight, cannot subsist in the new system, without an augmentation of the relative weight, or a diminution of the absolute weight; which diminution is had by multiplying the weight by the ratio, which is always less than unity. This done, we find that the absolute weight, multiplied by the ratio, is to the relative weight as the distance of the centre of gravity of the body from the axis of equilibrium, is to the distance of the centre of gravity of the base of the fracture from the same axis; which is precisely the same thing with the general formula given by M. Varignon for the system of M. Mariotte. In effect, after conceiving the relative weight of a body, and its resistance equal to its absolute weight, as two contrary powers applied to the two arms of a lever, in the hypothesis of Galileo, there needs nothing to convert it into that of M. Mariotte, but to imagine that the resistance, or the absolute weight, is become less, everything else remaining the same. One of the most curious, and perhaps the most useful questions in this research, is to find what figure a body must have, that its resistance may be equal in all its parts, whether it be loaded with an additional weight, or as only sustaining its own weight.

To this end, it is necessary that some part of it should be conceived to be cut off by a plane parallel to the fracture, so that the momentum of the part retrenched be to its resistance in the same ratio as the momentum of the whole is to its resistance. These four powers act by arms of levers peculiar to themselves, and are proportional in the whole, and in each part, of a solid of equal resistance. From this proportion, Varignon deduces two solids, which shall resist equally in all their parts, or be no more liable to break in one part than in another. Galileo had previously found one of these, which is that in which the sides are parabolical: the other, found by Varignon, is in the form of a trumpet, which is to be fixed into the wall by its greater end; so that its magnitude, or weight, is always diminished in proportion as its length, or the arm of the lever by which it acts, is increased. It is remarkable, that, however different the two systems may be, the solids of equal resistance are the same in both.

The following is a general synopsis of the most important results which have been drawn by different writers on this subject, both practical and theoretical.

1. The resistance of a beam or bar, to a fracture, by a force acting laterally, is as the solid made by a section of the beam in the place where the force is applied, into the distance of its centre of gravity from the point or line where the breach will end.

2. In square beams, the lateral strengths are as the cubes of their breadths or depths.

3. In cylindric beams the resistances or strengths are as the cubes of the diameters.

4. In rectangular beams, the lateral strengths are conjointly as the breadths and squares of the depths.

5. The lateral resistance of any beams, whose sections are similar figures and alike placed, are as the cubes of the like dimensions of those figures.

6. The lateral strength of a beam, with its narrower face upwards, is to its strength with the broader face upwards, as the breadth of the broader face to the breadth of the narrower.

7. The lateral strengths of prismatic beams of the same materials, are as the areas of the sections, and the distance of their centre of gravity, directly, and as their lengths and weights reciprocally.

8. When the beam is fixed at both ends, the same property has place, except that, in this case, we must consider the beam as only half the length of the former.

9. Cylinders and square prisms have their lateral strengths proportional to the cubes of their diameters, or depths, directly, and their lengths and weights inversely.

10. Similar prisms and cylinders have their strength inversely proportional to their linear dimensions.

The following results are wholly drawn from experiments on different substances, by Emerson and other writers, by means of which the propositions stated in the preceding part of this article may be submitted to computations.

The relative Resistances or Strengths of Wood and other Bodies.

	Proportional Resistance.
Box, yew, plum-tree, oak	11
Elm, ash	8½
Walnut, thorn	7½
Red fir, holly, elder, plane crab-tree, apple-tree	7
Beech, cherry-tree, hazel	6⅔
Alder, asp, birch, white fir, willow	6
Iron	107
Brass	50
Bone	22
Lead	6½
Fine free-stone	1

A cylindric rod of good clean fir, of an inch circumference, drawn in length, will bear at its extremity 400lb.; and a spear of fir, of two inches diameter, will bear about seven ton weight. A rod of good iron, of an inch circumference, will bear nearly three ton weight. A good hempen rope of an inch circumference, will bear 1,000lb. at its extremity. Hence Emerson concludes, that if a rod of fir, or a rope, or

a rod of iron, of d inches diameter, were to lift a quarter of the extreme weight that they would support, then

The fir would bear . . $8\frac{4}{5}\ d^2$ hundred weight.
The rope . . . . . $22\ d^2$ ditto.
The iron . . . . . $6\frac{3}{4}\ d^2$ tons.

To these results we may add, from the experiments and investigations of Professor Robison, that a prism of white marble, an inch square and a foot long, bears about 500 lb. And that, from the various authors he has collected, the cohesive force of a square inch of gold, when cast, is about 20,000 lb; of silver, 40,000 lb.; cast-iron from 40,000 to 60,000 lb.; wrought iron from 60,000 to 90,000; soft steel, 12,000 lb.; razor steel, 15,000 lb.; oak and beech, in the direction of their fibres, from 8,000 to 17,000 lb.; willow, 12,000; cedar, 5,000 lb.; fir, 8,000 lb.; ivory, 16,000 lb.; bone, 5,000 lb; rope, 20,000 lb. And a cylinder, an inch in diameter, loaded to one-fourth, will carry, if of iron, 135 cwt.; of rope, 22 cwt.; oak, 14 cwt.; and fir, 9 cwt.

The resistance of some metals is doubled, or tripled, by the operation of forging and wire-drawing; and the cohesive, as well as the repulsive force of wood, is often increased by moderate compression. Oak will *suspend* much more than fir; but fir will *support* twice as much as oak; which difference is supposed to arise from the curvature of the fibres of oak; yet oak has been known to support, with safety, more than two tons for every square inch. Stone will support from 250 to 850,000 pounds, on a foot square; brick, 300 lb.; and sometimes they are practically made to support one-sixth as much. Stone is said to be capable of bearing a much greater weight in that position in which it is found in the quarry, than in any other position.

RESOLUTION OF FORCES, the division of a force into two separate forces, acting in different directions, which shall have an equivalent effect to the original force. *See* Forces.

RESPOND, a half pillar or pier attached to or abutting against a wall.

RESSAULT, (French) the effect of a body, which either projects, or falls back, *i. e.* stands either more out or in than another; so as to be out of the line, or range, with it.

The term is little used in English; though the want of a word of equal import pleads for its naturalization.

RETAINING WALL, a wall erected for the purpose of retaining earth, or other loose or shifting material, and preventing slips and similar accidents; such are the wing-walls of bridges, &c.

RETICULATED, a term applied to any plane surface, formed into squares by chequered lines. The use of reticulation is to make a drawing similar to a given original, in the easiest manner: for this purpose, the original is divided into squares, and the size of the drawing, required to be copied, is divided into the same number of squares; then tracing the lines through all the squares as they appear in the respective squares of the original will give the outline of the design.

RETICULATED WORK, a kind of masonry or brick-work, formed of small square stones or bricks, set lozenge-wise, and presenting the appearance of net-work on the face.

RETRENCHMENT, (from the French, *retranchment*, formed of *re*, and *trancher*, to cut) in architecture, carpentry, &c., is used not only for what is cut off from a piece when too large, in order to better proportioning it, or some other convenience, but also for the projectures taken out of streets, public ways, &c., to render them more even, and in a line.

Retrenchment, in war, denotes any kind of work cast up to strengthen or defend a post against the enemy. Such are ditches, with parapets, gabions, facines, &c. for a covering, &c.

Retrenchment, (in fortification) is more particularly used for a simple ritirade made on a hornwork, or bastion, when it is intended to dispute the ground inch by inch.

RETURN, in building, denotes a side, or part that falls away from the front of any straight work.

RETURN BEAD, a bead which appears on the face and edge of a piece of stuff in the same manner, forming a double quirk.

REVELS (pronounced *reveals*, from the Latin, *revello*, to retract or draw back) the vertical retreating surface of an aperture, or, the two vertical sides of the aperture, between the front of the wall and the windows or door-frame, most commonly posited at right angles to the upright surface.

The revels of windows, in common brick buildings, are generally $4\frac{1}{2}$ inches in breadth, receding from the face of the wall to the sash-frame; but, in massy stone buildings, they ought to be of greater thickness, according to the magnitude or dimensions of the aperture.

REVOLUTION, (from the Latin, *revolvo*) in geometry, the motion of any figure quite round a fixed line as an axis. Thus, a right-angled triangle, revolving round one of its legs as an axis, generates by that revolution, a *cone*. *See* Cone.

RHOMB. *See* Rhombus.

RHOMBOIDES, (Greek) a quadrilateral figure, whose opposite sides and angles are equal, but which is neither equilateral nor equiangular; or, it is an oblique-angled parallelogram.

RHOMBUS, or Rhomb, (from the Greek, ῥεμβω, *to encompass*, or *turn round*) an equilateral rhomboid; or a quadrilateral figure, whose sides are equal and parallel, but the angles unequal; two of the opposite ones being obtuse, and the other two acute.

RIB, (Saxon) an arch-formed piece of timber. Also the projecting moulding on the soffit of a vaulted roof, which divides the vault into severies or compartments; and serves to conduct the thrust of the vault to the pier erected for its support.

RIBBING, the whole of the timber-work for sustaining a vaulted or coved ceiling.

RIBET, a term used in Scotland for the recess made in the sides of apertures of stone or brick work, to admit of door or window-frames.

RIBS, arch-formed timbers for sustaining the plaster-work of a vault, or coved ceiling.

RIDGE, (from the Saxon, *hrigg*) the highest part of the roof, or covering of a house. The term is particularly used for a piece of wood in which the rafters meet.

RIDGE-TILE. *See* Tile.

RIGGEN, a provincial term for the ridge of a roof.

RIGHT ANGLE, an angle which subtends a quadrant or quarter of a circle, containing 90 out of the 360 degrees into which the circumference is divided.

ROADS, as regards the history of road-making, the first steps towards the construction of permanent and durable roadways are said to have been taken by the Greeks, and also that this people expended considerable care and labour in their construction. But more noted than the Greeks in this matter, were the Carthaginians, from whom the Romans are by some reported to have derived their success in similar works. The first Roman road was constructed during the censorship of Appius Claudius, about 309, B.C.; it was first carried to Capua, and afterwards extended to Brundusium, a length of 350 miles; its breadth is about 14 feet, and its

thickness, 3 feet; the paving being laid upon a foundation of rough stones cemented with mortar, and that again upon a bed of gravel. This road is still entire; it was called the Via Appia in honour of the consul, as was the second, the Via Aurelia, and the third the Via Flaminia. In the time of Julius Cæsar, the number of roads had greatly increased, so that all the principal cities of Italy were connected with Rome by paved roads, and from that period such means of communication began to be extended into the provinces, their principal object being to provide a ready mode of access into distant provinces, for the passage of troops and similar purposes.

Augustus, when emperor, paid more attention to the great roads than he had done during his consulate. He conducted roads into the Alps; his plan was to continue them to the eastern and western extremities of Europe. He gave orders for making an infinite number in Spain; he enlarged and extended the Via Medina to Gades. At the same time, and through the same mountains, there were opened two roads to Lyons, one of them traversed the Tarentaise, and the other was made to the Alphenin.

Agrippa seconded Augustus ably in this part of his government. It was at Lyons he began the extension of roads throughout all Gaul. There are four of them particularly remarkable for their length, and the difficulty of the country through which they passed. One traversed the mountains of Auvergne, and penetrated to the bottom of Aquetaine. Another was extended to the Rhine at the mouth of the Meuse, and followed the course of the river to the German Ocean; the third crossed Burgundy, Champagne, and Picardy, and ended at Boulogne-sur-mer; the fourth extended along the Rhone, entered the bottom of Languedoc, and terminated at Marseilles. From these principal roads, there were an infinite number of branch roads, namely, to Treves, Strasburg, Belgrade, &c. There were also great roads from the eastern provinces of Europe to Constantinople, and into Croatia, Hungary, Macedonia, and to the north of the Danube at Torres.

The seas were able to cut across the roads undertaken by the Romans, but not to stop them. Witness Sicily, Corsica, Sardinia, England, Asia, and Africa, the roads of which countries communicated with the roads of Europe by the nearest ports. What labours! when we embrace in one point of view, the extent and the difficulties which opposed themselves—the forests opened, the mountains cut through, the hills lowered, the valleys filled up, the marshes drained, and the bridges that were built.

"The Roman roads," says Mr. Tredgold, "ran nearly in direct lines; natural obstructions were removed or overcome by the effort of labour or art, whether they consisted of marshes, lakes, rivers, or mountains. In flat districts, the middle part of the road was raised into a terrace.

"In mountainous districts, the roads were alternately cut through mountains, and raised above the valleys, so as to preserve either a level line or a uniform inclination. They founded the road on piles, where the ground was not solid; and raised it by strong side-walls, or by arches and piers, where it was necessary to gain elevation. The paved part of the great military road was sixteen Roman feet wide, with two side-ways, each eight feet wide, separated from the middle way by two raised paths of two feet each."

Even to such a remote province as Britain were such means of communication opened, good evidence of which still exists in the present day. In this country, a grand trunk, as it may be called, passed from the south to the north, and another to the west, with branches in almost every direction that general convenience and expedition could require. What is called the Watling street, led from Richborough, in Kent, the ancient Ruterpiæ, north-east through London to Chester. The Ermine street passed from London to Lincoln, thence to Carlisle and into Scotland.

The fossway is supposed to have led from Bath and the western regions north-east, till it joined the Ermine street. The last celebrated road was Ikeneld or Ikneld, supposed to have extended from near Norwich southward into Dorsetshire.

If we carefully trace the distance from the wall of Antoninus in (Britain) to Rome, and from thence to Jerusalem, it will be found that the great chain of communication from the north-west to the south-east part of the empire, was drawn out to a length of 4,080 Roman miles, or 3,740 English miles; the public roads were accurately divided by milestones and ran in a direct line from one city to another, with very little respect for the obstacles either of nature or private property; mountains were passed, and bold arches thrown over the broadest and most rapid streams. The middle part of the road was raised into a terrace, which commanded the adjacent country, and consisted of several strata of sand, gravel, and cement, and was paved with large stones, which in some places near the capital were of granite. It is estimated that the Romans constructed, in all, not less than 14,000 miles of paved roadway.

Since the Romans, no country seems to have surpassed or even equalled them in the hardness and durability of their roads; in England we may presume that this branch of engineering has been carried on with greater succes of late years than in any other country of modern times; we say of late years, for it was not until the latter half of the eighteenth century, that any considerable improvement was effected; the roads previous to that period having been of a most rude and unsatisfactory description. The greatest share of praise for improvement in the construction of roads, is due to Mr. Telford, the eminent engineer, who reduced the practice into a system conformable to the laws and requirements of science.

Practice of road-making.—The first object to be attended to in the formation of a road, is the preparing of a good solid foundation; for on this, more than on anything else, depends the durability and convenience of the road. This premiss has been denied by some persons, and the contrary assertion put forward by Mr. McAdam, a name which has become intimately associated with road-making, from the circumstance of that gentleman having introduced into England that system which has been named after him, and is known under the title, "Macadamized." This gentleman we believe was the first publicly to maintain the opinion, that an elastic road was equally good as one with a firm unyielding surface, and not only so, but even preferable. In a publication on this subject, he says—

"That a foundation or bottoming of large stones is unnecessary and injurious on any kind of subsoil.

"That the maximum strength, or depth of metal, requisite for any road, is only ten inches.

"That the duration only, and not the condition of a road, depends upon the quality and nature of the material used.

"That freestone will make as good a road as any other kind of stone.

"That it is no matter whether the substratum be soft or hard."

In contradiction to such assertions as these, we have the universal experience of practical men, and the testimony of both practical and scientific men, such as Telford and Lardner.

To comprehend thoroughly the great importance of making

a regular and strong foundation, it should be borne in mind that roads are structures that have to sustain great weights, and violent percussion; the same rules, therefore, ought to be followed with them as are followed with regard to other structures. A road will never be of long duration, nor at any time in a satisfactory condition, which has not a firm and substantial foundation. But not only is its durability affected under such circumstances, it has disadvantages in other points equally important and essential to a good roadway. Besides the durability of a structure, we have to consider its economy, and its adaptation to the special purpose for which it is intended. Now, the object to be attained by a good road is the conveyance or transport of goods in the readiest and most economical manner, so that the constantly-occurring expense of transit ought to be taken into even more careful consideration than the original outlay upon the road itself; we want goods to be conveyed at as small an expense as possible. Now, the largest item in the expenditure for the conveyance of goods consists in the expense of the power employed; and as much as we can reduce the amount of this power, by so much do we reduce the expense likewise. According to all experience, as well as science, the power required to draw a carriage, or any body, over a yielding or elastic surface, is much greater than that required to draw the same over a hard unyielding surface; and the reason is plain—there is not so much friction in the latter case as in the former, and the surface in contact with the wheels of the conveyance is not so great as on a yielding roadway. "The resistance," says Professor Leslie, "which friction occasions, partakes of the nature of the resistance of fluids; it consists of the consumption of the moving-force, or of the horse's labour, occasioned by the soft surface of the road, and the continually depressing of the spongy and elastic substrata of the road. In fact, on a yielding roadway, the carriage or waggon has to be drawn over a series of hillocks, for, as the load passes over it depresses that portion of the road immediately beneath it, and has before it, to be passed over in its turn, a portion which has not yet undergone this process: the comparison between the tractive power employed on roads of different elasticities, has been well illustrated—thus:—An ivory ball set in motion with a certain velocity over a turkey carpet, will suffer a visible relaxation of its course; but with the same impelling force it will advance farther, if rolled over a superfine cloth; still farther over smooth oaken planks; and it will scarcely seem to abate its velocity over a sheet of fine ice."

The fact of greater tractive power being required in elastic than in hard roads has been proved beyond a doubt, by the experiments made by Sir John Macneil, by his machine invented for this purpose.

These experiments uniformly show, that the force of traction is in every case in an exact proportion to the strength and hardness of a road. The following are the results on a well-made pavement:—The power required to draw a waggon is 34 lbs.; on a road made with 6 inches of broken stones of great hardness, laid on a foundation of large stones set in the form of a pavement, the power required is 46 lbs.; on a road made with a thick coating of broken stone, laid on earth, the power required is 65 lbs.; and on a road made with a thick coating of gravel, the power required is 147 lbs.: thus it appears that the results of actual experiments fully correspond with those deduced from the laws of science.

Sir John, in his examination before a Commitee of the House of Commons in 1836, says, "The great advantage of the roads appearing by the machine is certainly in proportion to their solidity and their strength, and their want of yielding. If it could be a perfectly solid mass of stone or metal, the least resistance would be presented; that is shown both on stone tramways and on metal tramways, and metal rails."

This foundation should be composed either of a rough paving of large stones, or of a sufficient bed of concrete, the former being the practice of Mr. Telford, and the latter of many engineers of the present day; the selection of either of these materials will depend upon their economy in various places; whichever is most accessible, may be safely used; but whatever material be used, it is necessary that the substratum should be of uniform strength and solidity over the entire surface, otherwise, after the pavement has been laid, the weaker parts will give way, while the stronger maintain their position, and so the surface of the road becomes broken and uneven, rugged, and full of hollows; for this reason we prefer the use of concrete, which offers greater security against this defect than foundations made of large stones or rubble, though in many roads even concrete is not sufficient entirely to prevent it. We are inclined to think that the value of concrete for this purpose has not been fairly tested, for the work, especially in London roads, is usually got through in so hurried a manner as not to allow a sufficient time for setting: we imagine, that with a somewhat thicker bed of concrete, the materials of which have been properly mixed, and allowed a sufficient time to set before the metalling is put on, we should be enabled to construct roads sufficiently firm to bear the extraordinary wear and tear of London traffic, and that, too, at a less cost than is expended on the present roadways. We are aware that there are many disadvantages to contend with in London roads; that they are continually being pulled up, and thereby destroyed, for works connected with water, gas, or sewers, and that this acts as a great discouragement to the construction of good roads. That any necessity of this nature should be allowed to exist is much to be lamented, but we feel confident that such practices might be restricted to a very considerable extent, without doing any injury to the public convenience. The concrete foundation should be slightly curved, falling from the centre towards both sides, which form will assist to drain it, and also to give the proper form to the surface of the roadway. It is necessary that this lower surface should be properly drained, otherwise the water will lie there, and destroy the road. If the concrete were laid 18 inches thick, we should not deem the extra expense ill laid out for a good road. With respect to the other kind of foundations, Mr. Parnell says—"In streets where the traffic is not very great, the foundation should be made in the following manner:—A bed should be formed, with a convexity of 2 inches to 10 feet, so as to admit of 12 inches of broken stone being laid upon it: these should be put on in layers of four inches at a time. After the first layer is put on, the street should be kept open for carriages to pass over it. When the first layer has become firm and consolidated, then another layer of 4 inches should be laid on, and worked in as before, care being taken to rake the ruts and tracks of the wheels of carriages, so that the surface may become smooth and consolidated. The same process should be repeated with the third layer of stones, by which means a solid and firm foundation will be established, of 12 inches in thickness, for the dressed paving-stones to lie upon." Such directions deserve greater attention than we fear they usually receive; in all cases, let your foundation be secure before you lay your roadway.

Various kinds of materials are used for the purpose of forming the upper coat of the road, and amongst those most frequently employed may be mentioned broken Guernsey granite, flints, gravel, and cubes of granite of

various sizes. Of these the broken granite and granite cubes are most useful, the one for general purposes, the other for roads which are subject to great wear and tear, such as those n the principal thoroughfares of London, for although both lescriptions of material are used for this purpose, yet we are nclined to think that the broken stone is scarcely durable enough for such work: and there is this further objection to it, that it is constantly requiring repairs, which must, to a certain extent, inconvenience public business. Besides this, as usually managed, they occasion a great deal of dust and dirt, while the draught of vehicles upon them is very heavy, and their maintenance expensive. It would be scarcely fair, however, to attribute the faults of management to the quality of the material, and we believe that many of the above objections may be removed by skilful management.

In the first place, as regards durability, the objection would be removed to a considerable extent by employing a good foundation, and laying the metal carefully upon it, providing for the proper drainage of surface and substratum as mentioned above, for the lodgment of water either above or below such roads is very injurious, and tends, perhaps more than anything else, to their destruction. Having obtained a good foundation, the next point is to cover it with a hard compact crust impervious to water, and laid to a proper cross section, so that it may be speedily drained and no water be allowed to remain on the surface, which, besides its inconvenience to passengers, is very destructive to the surface of the road. A practice has come into vogue of late, of covering the road when made, with a binding composed of the grit collected off the road in wet weather, and by the operation of water-sweeping. The binding is laid on regularly and watered until the new material is firmly set, which it does very quickly, and when the binding is of good quality and properly laid on, it assists its formation very considerably, and altogether improves the condition of the road and economizes the material, for it saves the wear and attrition of the new stone. Some road-makers object to this binding on the ground, that it destroys or rots the road, and that when the road is set it has to be carted away again; but this is only the case where improper binding is used, such as is swept from streets which are not properly cleansed, and therefore consists principally of mud, and not of grit, or rather of grit so mixed with dirt as to be for the most part useless for binding. This method of binding a road removes in part the objection which is made against the resistance occasioned by the loose stones of a newly-laid broken road.

We alluded just now to the cleansing of roads, and it is a matter which deserves considerable attention, and is applicable to every variety of road; a dirty road is a constant source, only not of inconvenience, but of expense, for scarcely any thing destroys a road more readily than dirt. And not only is this the case, but the tractive power also required on a dirty road is twice as great as that required on a clean one: when we come to add to this the damage done to property by the mud in wet weather, and the dust in dry, we shall be able to form some notion of the waste occasioned by dirty roads.

The best method of cleansing roads is by water-sweeping: a method of watering and sweeping combined, the roads being first watered and then swept, by which means the road is thoroughly washed from its impurities. The watering is usually carried on by means of a water-cart, but a more effectual means, as far as the cleansing of the road is concerned, is afforded by the hose and jet. The sweeping is mostly effected by hand, and in some places this method is carried on systematically, which is an improvement upon the old practice; but of all methods offered to the public, that of Whitworth's sweeping-machine, is the most effective, and in the end, we believe, the most economical, By this machine an endless chain of brooms is made to revolve by the motion of the wheels, and to sweep the dirt immediately from the roads up an inclined plane into the cart, without fear of splashing, or any other annoyance to the public, which is a vast improvement on the old practice of stacking the mud or dust up in heaps, and letting it remain in that state until the carts come round, during which period a considerable portion of it had probably been spattered about by the traffic, or blown in all directions by the wind, and even then passengers must expect to be bespattered by the negligent manner in which the refuse was carted away. This machine, too, presents other advantages, in the width of the brooms, and the uniform pressure exerted throughout, a pressure which can also be regulated as occasion demands. Water-sweeping by this machine is, we venture to assert, one of the best, if not the best method of cleansing roads, and our assertion is supported by facts. It has been objected that water-sweeping removes the material of the road, but the contrary has been proved to be the case. Mr. Smith, the eminent surveyor of Birmingham, says, "I have found that the use of sweeping-machines, with the proper employment of water, has reduced the amount of material required for the repair of roads in Birmingham one-third, viz., from 20,000 to 13,000 cubic yards; the first named amount is the average of seven years preceding the introduction of the machines, the latter of the three years subsequent." On the 22nd of March, 1848, some experiments were made upon the subject in the Quadrant, Regent-street, the road being then covered with a thick coating of dust, which was causing great annoyance as well as injury to the road, but could not be removed by scraping without removing also much of the new stone to which it adhered. It was determined to sweep half of it dry, and half after proper watering. This was done, and the sweepings removed were washed, to separate the refuse from the stony matter mixed with it; one third part of that which was taken dry consisted of coarse grit which would have been useful on the road; one-twelfth part only of that which was removed in the form of slop was stony matter, and that was so completely pulverized as to be of scarcely any use—it had done its work. After the two portions of the road had been cleansed, the difference between them was very striking. That which was swept dry was still covered with adhesive matter, which, together with the stones to which it adhered, was lifted by the wheels, the whole road being rough and uneven. The portion which had been swept with water was perfectly even and smooth. On the 24th both portions were swept, but only one quarter as much dirt was taken from that which had been water-swept as from the other. On the 26th it rained, and three times as much slop was taken off the part of the road which had not been water-swept on the 22nd. The preservative effect of water-sweeping by machine was most striking, by the decidedly better condition of that portion of the road cleansed in this effective manner.

The granite-cube roads are preferable to macadamized in point of durability, and therefore are more eligible in this respect for places where there is great traffic, but nevertheless there are objections which partly outweigh these advantages, one of which, of considerable importance, arises from the circumstance of the wear and tear of vehicles being very great on such roads on account of the frequency and violence of the concussions to which they are subject; and although the draught upon macadamized roads is, generally speaking, heavier than upon pavement, yet this advantage is probably more than neutralized by the concussions alluded to, which form a great impediment and injury to vehicles travelling quickly

Another objection is, that a horse has not nearly so secure a footing upon paving as upon a broken-granite road.

A system of tram-roads has been adopted for special traffic on some roads with great advantage, as in the Commercial and East India Dock roads, where two parallel lines or tramways of masonry are laid for the wheels to run upon, the space between being paved with the ordinary paving. These trams were made of large blocks of granite 5 or 6 feet in length, 16 inches wide, and 12 inches deep, and have been found to stand the heavy traffic much better than ordinary pavement would have done.

Roads paved with blocks of wood are of comparatively recent invention, and offer many advantages over common roads, in the evenness of the surface, but more especially by the prevention of noise, which is a great inconvenience on paved roads. It is to be regretted, however, that with such advantages it has defects, which, until removed, will put an effectual bar to its general employment; we allude to its want of durability, and consequent expense, but more especially to its slipperiness in wet and damp weather. The former objection we feel confident may be removed by employing greater care in the construction and drainage of the substructure; and the latter has been remedied, in some degree, by spreading broken granite on the surface.

In concluding this article, we beg to recapitulate the principal points to be attended to in the construction and management of roads:—viz.; a good solid foundation, proper drainage, and efficient cleansing. We subjoin a table of the comparative costs of various kinds of Roads with some cursory observations on their peculiarities.

A Table showing the comparative First Cost, Annual Expense, and Durability, of different descriptions of Carriage-Roads, as for example, in a road 42 feet wide, with ordinary substratum.

Material used.	First Cost for square yard.	Cost for square yrd. per annum for repairs.	Value of materials at end of			Observations on durability and condition the road would be in at the end of 20 years.	Cleanliness.
			10 yrs.	20 yrs.	30 yrs.		
Guernsey Granite, or Macadamized road.[a]	4s. 6d.	1s. 6d.	3d.	3d.	3d.	The price in each case is taken for London wear; as in the principal thoroughfares at the West End, the road being always renewed at the expense stated, the value of materials would be the same at each period.	The mud in wet and the dust in dry weather, are the chief objections to these roads; they are very expensive to keep clean.
Grueby & Whinstone.	about the same	see 2d column					Grueby stone turns to a light mud in bad weather, and roads made with it, cost more to keep clean than granite roads.
Ightam stone, a small quantity of this stone is sometimes sent into the London market.	3s. 6d.	2s.	nil.	nil.	nil.	This material will not bear the traffic granite will; it has been used in streets of secondary traffic, but grinds to powder in dry, and goes off to light mud in wet weather.—The same remarks as above as to value at 20 years.	Same remarks as made upon Grueby stone, apply to this in reference to cleansing the roads.
Flints.....	3s.	2s. 3d.	nil.	nil.	nil.	The same observations which have been made in reference to Ightam stone, apply in a still stronger degree to flint roads, as they are much inferior in durability, though well suited to some localities.	Very difficult to keep clean.
Aberdeen Granite, 3-inch cubes, concrete foundations.[b]	17s. 6d.	For the first 3 yrs. nil, afterwards 3d. per annum.	7s.	4s.	2s. 6d.	The price named as value of a certain number of years' wear, is what the materials would sell for if removed. They would be worth more, if removed to other streets.	This is the best and cleanest of pavements, as it offers the greatest facilities for washing.
Cubes.							
9 inch deep by 5 wide[c]	14s.	do.	6s. 6d.	4s.	3s.	Do.	Good pavement, but not so clean.
Wood.							
Metropolitan Wood-paving Comp.; Concrete foundation included.[d]	12s. 6d.	1s. 6d.	The value of material when relaid at the end of every eight years, 1s. per square yard.			The price named as for annual repairs, is sufficient to lay with new when required, and it is presumed this would be necessary at the end of every eight years.	Wood offers great facilities for cleansing; it is swept easier, and at less cost, and the sweepings are valuable for manure, while the sweepings of broken-stone roads are not. It can be easily washed also, but should not be kept wet, if possible to avoid.
There are other forms of Wood Pavement, but none equal to the above.							

Remarks.

[a] The Guernsey granite is the only material which has been found to stand the extraordinary wear and tear of London traffic, all other stone has failed, or has not been procurable at a reasonable price.

[b] The annual cost of repairs depends not only on the traffic over the road, but on its good or bad formation originally. Some part of the New Road, for instance, is made on so bad a bottom, that in wet weather, the substratum works up, and destroys the new material. An eminent contractor, some time since, sent in an estimate, to take out the substratum to a certain depth, fill in with good hard stuff, and make them a good road over it. This done, he would have undertaken to keep the road in repair at 1s. per yard per annum.

A road made with the centre of granite, and sides of flints, has been found to answer well in the neighbourhood of London; also flints in the centre, and the sides paved with granite stones, (cubes.)

[c] This is not equal to the 3-inch cubes described above.

[d] The first cost of this description of road, has alone prevented its becoming more general; but there seems little reason to doubt, that it will be found almost the only pavement suited to London wear.

The contract price for keeping in repair Regent-street, is 6d. per square yard per annum for 7, 14, or 21 years.

This piece of wood has been strewed with clear Guernsey Granite, broken in small pieces, which has been found in a great degree to prevent the slipperiness so much complained of. The expense of the experiment borne by the Commissioners, was £125, or about 2d. per yard.

ROD, a linear measure of 16½ feet. Also a superficial measure of 272¼ square feet, by which brickwork is usually calculated; the rod contains 272¼ square feet of brickwork, a brick and half thick, or 306 cubic feet.

ROE-STONE, or 'Oolite, a variety of limestone, composed of small round globules, resembling the roes of fishes, imbedded in a calcareous cement. These globules are composed of concentric lamellæ, and are evidently the result of crystallization. They vary in size from a grain of mustard-seed to that of a pea: when they are as large as the latter, it is called *pea-stone*. Roe-stone is one of the secondary limestones, which may be considered as belonging to the chalk-formation. It lies under chalk in various parts of England, being separated from it by beds of sand and clay. It is found also in many parts of Europe; but, according to Humboldt, is not met with in South America. Some of the strata of this stone are extensively used for purposes of architecture: the most distinguished are the Ketten stone, in Northamptonshire; the Bath firestone, in Somersetshire; and Portland stone, in the island of Portland. Portland stone is of a yellowish-white colour: the more compact varieties, when closely inspected, show a tendency to crystalline arrangement; it is composed of carbonate of lime, with a small admixture of silex and alumina.

ROLL-MOULDING, a moulding in Gothic architecture of a circular section, though frequently interrupted or broken by a fillet.

ROLLS or Rollers, among carpenters, masons, &c., plain cylinders of wood, seven or eight inches in diameter, and three or four feet long; used for the removing of beams, huge stones, and similar burdens, which are cumbersome, but not exceedingly heavy. These rollers are placed, successively, under the fore part of the masses to be removed; which, at the same time, are pushed forward by levers, &c., applied behind.

When blocks of marble, or other excessively heavy loads, are to be removed, they use what they call *endless rolls*. These, to give them the greater force, and prevent their bursting, are made of wood joined together by cross-quarters; they are about double the length and thickness of the common roller, and, besides, are girt with several large iron hoops at each end. At a foot distance from the ends are four mortices, or rather only two, but pierced through and through, into which are put the ends of long levers, which the workmen draw by ropes fastened to the ends, still changing the mortise, as the roll has made a quarter of a turn.

ROMAN ARCHITECTURE. The early Romans can scarcely be said to have possessed any style of architecture of their own, but borrowed their ideas of building first from the Etruscans, and, at a later period, from the Greeks. In the time of Romulus, their buildings would seem to have been of the most rude description, their dwelling-houses being composed chiefly of straw, and thence termed culmina; and at a somewhat later period, even their temples were only small square erections scarcely large enough to contain the statue of the deity.

Ancus Martius was the first king who commenced works of a larger class requiring skill in their construction, and his first attempt was the construction of the city and port of Ostia, at the mouth of the Tiber. Tarquin the Elder brought with him the skill and enterprise of the Etruscans, and set about improving the city with energy and perseverance; his first work was to erect the grand circus; he also constructed the walls of the city with large hewn stones, and commenced the great cloaca, or public sewer, as well as the temple of Jupiter Capitolinus, which was continued by Servius Tullius, who also enlarged the city. Tarquinius Superbus yielded to none of his predecessors in the decoration and improvement of the city. During his reign the circus was completed, as was also the cloaca maxima, which was considered one of the wonders of the world, and still remains as a monument of the enterprising spirit of the Tarquins. It was constructed of wrought stone, and was of such dimensions, that a wagon loaded with hay could pass through it; and was carried through rocks and under hills, and many were the engineering difficulties overcome in its construction. The temple of Jupiter Capitolinus was not completed till after the expulsion of the kings, but was considerably advanced by this king.

After this period, some of the principal works were—the completion of the Capitol, commenced by Tarquinius, the formation of the Campus Martius, and the outlet for the relief of the lake Alba. In the year 389, B. C., the city was burned by Brennus, which afforded an opportunity for rebuilding it in a more convenient and sumptuous manner; but unfortunately, the opportunity was not taken advantage of, and the houses were erected after a more irregular plan than they had previously been; for whereas, in the old city, the public sewers ran under the roadway; in its re-edification, the streets were laid out without any reference to this arrangement—a want of consideration, the effects of which were greatly felt at a subsequent period.

During the censorship of Appius Claudius, 309 B.C., the first paved road was laid by the Romans; it extended from Rome to Capua, and afterwards to Brundusium, a length of 350 miles, and is to be seen at the present day. It was 14 feet in width, and about 3 feet deep, being composed of three thicknesses, the lower one consisting of rough stones grouted together, the second of gravel, and the third of stones of various dimensions, but so accurately pointed, as to have the appearance of a single stone. The credit of constructing the first aqueduct also belongs to this censor, by which a supply of water was conveyed from Præneste to Rome, by means of a deep subterraneous channel upwards of 11 miles in length. During the two first Punic wars, many temples were erected, but they do not appear to have been of great magnificence. Cato adorned the city with a basilica, which he named Portia, and Sempronius erected a second, which was called after his own name.

The censors Fulvius Flaccus and A. Postumius Albinus, contributed much to the embellishment of the city; they paved it, adorned it with porticos, enlarged the circus, and made public ways and bridges on the outside. At this period, the more wealthy Romans began to live out of the city, and build country-residences, which were, in many cases, of considerable extent and luxurious decoration. To such an extent was the magnificence of these villas carried at last, that we find Cicero in the habit of employing no less than two architects.

All this time but little taste had been exhibited in the decoration of their buildings, which were mostly of brick, or, at best, of stone obtained in the neighbourhood; but as their conquests extended, and they became intimate with the more costly buildings of their enemies, they began to entertain more expanded ideas of magnificence in art. Metellus Macedonicus, the contemporary of Mummius, the victor of Corinth, was the first to build at Rome a temple of marble; but from this time most of the larger edifices were constructed of this material. At this period also, Grecian art and architects were introduced, and many works of art brought thence to decorate Rome; Sulla carried away the columns, &c., from the temple of Jupiter Olympius at Athens, to embellish that of Jupiter Capitolinus at Rome.

The first permanent theatre was erected by Pompey; previous to his time, such erections were not allowed to remain

after the shows, and therefore only temporary buildings were erected for the purpose. Of these, however, some were of great size and magnificence; M. Æmilius Scaurus, when ædile, erected one capable of containing 80,000 persons, which is reported to have been sumptuously decorated. Another theatre was erected by Curio, one of Cæsar's partisans, which exhibited great mechanical skill. Two large theatres of timber were constructed back to back, and on one side so connected with hinges and machinery for the purpose, that when the theatrical exhibition had closed, they were wheeled or slung round, so as to form an amphitheatre, wherein, in the afternoon, shows of gladiators were exhibited. Pompey's theatre was built of stone, and was made capable of accommodating 40,000 persons; it was surrounded by a portico for shelter in case of unseasonable weather, and had attached to it a curia provided with a basilica, or hall of justice, as also a temple dedicated to Venus.

Under the auspices of Julius Cæsar, many new and magnificent buildings were erected. On his return from Utica, after his threefold victory, he brought into the treasury no less than 65,000 talents, and 2,822 crowns of gold, which afforded him every facility for carrying out his magnificent projects, amongst which may be mentioned the extension of the circus, and formation of a lake for the exhibition of Egyptian and Tyrian galleys, a new forum, two temples to Venus, one of which was on an exceedingly grand scale, and a third to Clemency. Besides these, he commenced a vast theatre, the drainage of the Pontine marshes, the improvement of the navigation of the Tiber, by forming a new bed from Rome to the sea, a canal through the Isthmus of Corinth, the formation of a port at Ostia, and of a causeway across the Apennines, from the Adriatic to Rome; add to this, the rebuilding of Corinth and Carthage, and we shall be enabled to form a conception of the vast ideas and ready execution of this great man.

Such an introduction as this was worthy the golden age which followed in the next reign, an age which the peace purchased by the victorious arms of Cæsar had yielded to the cultivation of civil arts, and that excessive refinement which led the way to luxury and consequent ruin. In this reign most of the finest buildings were erected, and architects flocked from all quarters, and especially from Greece to assist in beautifying the city, the latter being highly esteemed and eagerly employed; in short, Greece at this time had become the standard of taste amongst the Romans, not only in the arts, but in customs and manners. Augustus had conceived the project of making Rome the most splendid city in the world; and not only set about embellishing it himself with the greatest ardour, but also incited his friends, and the principal personages of the empire to follow his example, which indeed they were not slow in following; and amongst the buildings erected by them may be mentioned, a temple of Hercules Musagetes, by Marcius Philippus; a temple of Diana, by L. Corfidius; of Saturn, by M. Plaucus; of Concord, and of Castor and Pollux, by Tiberius; the Atrium Libertatis, by Asinius Pollio; a theatre, by Cornelius Balbus; and an amphitheatre, by Statilius Taurus. His friend Agrippa was highly distinguished in this respect; he erected many magnificent buildings, aqueducts, baths, fountains, &c., but he stands preeminent above all his countrymen, by the erection of that monument of Roman skill and enterprise, the Pantheon. The principal edifices erected by Augustus himself were—the forum and temple of Mars Ultor; the temple of Apollo Palatine, with a portico and library; the temple of Jupiter Tonans, on the Capitol; the porticos of Livia and Octavia; the basilica of Caius and Lucius; the theatre of Marcellus; and a mausoleum for himself and family. After such an enumeration, the boast of Augustus will not appear a vain one, "that he found Rome built of brick, and left it of marble."

During the reigns of the immediate successors of Augustus, architecture fell into decline, and the only building of any importance which we hear of before Nero's time, is the Aqua Claudia, a large aqueduct, which was completed by Claudius. Its length was 46 miles, and for more than 10 it was carried on arches more than 100 feet above the level of the ground. Nero's edifices were gorgeous in the extreme, but more remarkable for expensive decoration than intrinsic merit of design; his Domus Aurea is a remarkable specimen of his prodigality in such matters; it was erected by two architects, Severus and Celar, and was most lavishly embellished, so that it would be difficult to form an idea of its expense.

Under Vespasian, and his successors, architecture again flourished, to which the remains of the Coliseum abundantly testify. This building was commenced by Vespasian, and completed by his son Titus, and its erection is said to have occupied no greater space of time than two years and nine months; it covers nearly six acres of ground, and was reported capable of containing 100,000 spectators. The reign of Titus is also remarkable for the erection of the baths and triumphal arch which bear his name. Trajan is the next name worthy of record, as a liberal patron of architecture, and amongst his works may be mentioned the forum, triumphal arch, and column which has never yet been surpassed. His bridge over the Danube, which was destroyed by Hadrian, was a bold undertaking; it is reported to have consisted of 20 stone piers, 60 feet wide, and 150 in height, the arches between being not less than 170 feet in span; his architect was Apollodorus, who fell a victim to his master's jealousy, for blaming his architectural plans. Few princes erected a great number of edifices than did Hadrian, amongst which were the Maison Carreé at Nismes, his villa and mausoleum, the amphitheatres at Capua and Verona, and the bridge over the Tagus at Alcantara. Besides these, he re-built Jerusalem, which he styled Ælia Capitolina, also part of the temple of Jupiter Olympius at Athens. In this reign also an aqueduct was constructed by Herodes Atticus to supply Troas with water, and, by the same man, a stadium at Athens 600 feet long, a stadium at Delphi, a theatre at Corinth, and baths at Thermopylæ.

Under the Antonines were erected the temple of Antoninus and Faustina, the Antonine column, and that of Marcus Aurelius, besides many other temples and works in the provinces, amongst which may be enumerated the re-building of Smyrna, Laodicea, and other Asiatic cities. After this period architecture gradually declined; a little improvement may be seen in the reigns of Septimius and Alexander Severus, but taste had greatly deteriorated, and art had fallen to too low an ebb to be restored. Antoninus Pius is reported to have erected the vast edifices of Balbec and Palmyra, but the subject admits of a doubt. Dioclesian made a bold effort to restore architecture to its original position, but it was beyond his power, and although his buildings, his baths, and his palace at Spalatro were magnificent in point of extent, and a certain kind of grandeur, yet they bear evident tokens of the state into which architecture had fallen. The palace at Spalatro covered between nine and ten acres, one of the sides being 600, and the other 700 feet in length; attached to it was a portico 500 feet long, embellished with painting and sculpture. Constantine was a great builder, but he transferred the seat of empire to Byzantium, and thus Roman architecture was superseded by the new style which he introduced in his new capital. This change, however, is to be the less regretted, inasmuch as Roman art had already degen-

rated beyond hope of restoration, and new edifices of barbarous design had begun to be erected at the expense of those of better design already in existence.

In comparing the relative merits of Greek and Roman architecture, there can be no question but that the former by far excels in matter of taste; and this, by many writers, seems to be the only question considered. But this is not fairly the whole point at issue between them; there are other matters to be brought under consideration; and such are—variety, as well in use as in design; the capability of being adapted to different purposes of life; as well as excellency and facility of construction. Now, although the Greeks far exceed their rivals in simple grandeur, chasteness of decoation, and correctness of detail, still it must be remembered that their structures are chargeable with sameness and monotony: their plans scarcely ever varied from the oft-repeated rectangle; the only change consisting in the different arrangement of the columns, and in the applications of the few orders of architecture which they possessed; the only variation in plan which occurs, is to be found in the Erechtheum at Athens, and some smaller monuments, as the Temple of the Winds, the Choragic Monument of Lysicrates, and such like. Grecian architecture was almost entirely devoid of composition; and no attempt was made in them of grouping their several parts, so as to produce a varied, yet effective, outline.

Now, on the other hand, the Romans were not so much a sentimental as a practical people; and this fact, we think, will account in a great measure for their different appreciation of the art under consideration. During the earlier period of their history, it will be found that they constructed only works of public utility and convenience, and whose only claim to beauty consisted in their magnitude, their grand conception, the mechanical skill employed in their construction, and their perfect adaptation to the purposes for which they were intended. The effect produced by them is rather surprise and admiration than pleasure; they awe by their grandeur, rather than satisfy by their display of taste. Such works would not be classed in the present day under the term architecture at all, but under that of engineering—two terms which are perfectly distinct in this application, although both applied to works of construction, to buildings, or artificial erections, the one, however, applies more especially to the science, the other to the art, of building; not that science is absent in either case, but that art—that is, fine art—in the one case stands pre-eminent, as scientific skill does in the other. Under the term engineering we should include the roads, bridges, aqueducts, and sewers, for which the early Romans are so noted, and whose mode of construction was probably learned from the Etruscans, who seem to have been a people of similar character, though of improved civilization, to the Romans. This practical character to which we allude, the Romans never entirely lost, even after they had become acquainted with the voluptuousness of Greece, and during the luxury of the court of Augustus and the succeeding emperors; for although at this period they began to cultivate architecture simply as one of the fine arts, still not even then did they lose sight of utility in their buildings.

With the Greeks, religion was almost the sole purpose for which architecture seemed to exist; with few exceptions, we have no other examples but temples: on the other hand, the temples of the Romans were neither so extensive nor so numerous as their works of public utility or convenience; and this also arises from their national peculiarities; for they were neither so religious, nor so philosophical and contemplative, as the Greeks. Amongst Roman remains, besides the engineering works which we have above alluded to, we have fora, baths, palaces, circi, theatres, amphitheatres, libraries, halls of justice, triumphal arches, commemorative columns, mausolea, and such like. The requirements which were necessary for such buildings as these, led, no doubt, to the practice of composition and grouping, for it is very certain that one uniform plan of building would not have been suitable for such a variety of purposes; but this was not the only cause of variety in their buildings, although, perhaps, the principal one. Another may be observed in the employment of the arch, which allowed much greater latitude of construction than the entablature of the Greeks; with the latter the intercolumniations were fixed to a certain gauge, or at least limited within a determinate range; whereas, with the former, every facility was afforded for increasing or diminishing the space between the piers to almost an unlimited degree. It is not improbable, too, that the semicircular form of the arch, which was in such constant use, assisted in the development and frequent employment of circular plans, or of plans in which circular and curved lines were introduced; for it is not unlikely that the existence of a form or figure in the elevation should suggest its application to the plan likewise. This employment of the circle in the plans of their buildings led inevitably to that which was quite a new feature in architectural design, the dome—a feature, too, which gave a totally distinct character to the buildings in which it was employed, and introduced an important element of variety into architectural design. Of this arrangement the Pantheon is the most remarkable example; and it requires none other, to attest to the importance of the change then introduced. The effect of the interior is strikingly different from anything which had before appeared; a vast area, such as that of the Pantheon, covered over by a single hemispherical dome, must, at the time of its erection, have produced a most wonderful and novel effect. Nor is the exterior devoid of novelty or character—a fact which is especially observable in the rectangular portico—projecting from a larger circular building. Such a combination forms a striking contrast to the uniformity of Grecian edifices. In the instance of the Pantheon, the exterior is destitute of columns, except in the portico. But there are many buildings in which the circular plan was carried out with an external peristyle: such, for instance, is the temples of the Sibyl; or, as it is otherwise named, that of Vesta at Tivoli. Buildings of this class were roofed with hemispherical domes, or with lesser segments of a sphere; but these were not visible on the exterior, being concealed by the projecting colonnade. Even in the Pantheon, where the dome is hemispherical, and of so great diameter, it does not form a conspicuous object on the outside, for its springing line is situated at about the level of the lower cornice; and its external height is still further reduced, by the base of the outer portion of the dome being formed into several courses of steps. Had the entire height of the dome been visible from the exterior, it would have borne by far too great a proportion to its base. In the time of Constantine, the circular plan was employed with an internal colonnade, as in the church of San Stephano Rotundo, and that of Sta Costanga; in both which cases, the circular portion within the colonnade is of greater elevation than that portion embraced between the colonnade and external walls, and is covered with a dome; but in Sta Costanga there is a further peculiarity, for the columns are not only coupled, but are arranged in an unusual manner, in pairs, one behind the other: the columns serve to support in arcade. Both these edifices have been claimed as heathen temples, (the one as dedicated to Faunus, and the other to Bacchus,) but seemingly without any other foundation than conjecture, and the existence of some decorations which are

applicable to the Christian religion, as well as to the heathen mythology. A more notable example of the circular form is the Church of the Holy Sepulchre at Jerusalem, built by the empress Helena, mother of Constantine.

The circular form was also a favourite one for tombs and mausolea, amongst the more remarkable of which are those of Augustus and Hadrian. The former consisted of four cylindrical stories, the diameter of each being somewhat smaller than that below it, and the uppermost crowned by a colossal statue of the emperor. The latter is now the well-known castle of St. Angelo, and originally consisted of a cylindrical building, placed upon a square base, the height of which was about half that of the superstructure. No remains are now left of the uppermost stage of the building, which was also circular, and was surmounted with a peristyle of 34 Corinthian columns; its diameter being about one-third that of the larger cylinder. Of a similar form is the tomb of Cecilia Metella, but devoid of the upper story. A more curious example is the sepulchral monument at St. Renie, which consists of three stories, the lowest a square base, raised on gradini, and covered on each side with sculptures in relief; the next square, with an attached fluted Corinthian pillar at the angles, and an open arch on each side; and the uppermost a Corinthian rotunda, forming an open or monopteral temple, in which are two statues. The tomb of Virgil consists of a square base, surmounted by a conical structure; and a cenotaph at Constantina, in Africa, has the lower story cylindrical, surrounded by a peristyle; while the upper is a lofty cone, formed in receding courses or steps. Edifices erected on polygonal plans were not uncommon, of which the octagonal were most frequent; the latter form was commonly employed in saloons to public baths; and there is an octagonal temple in Dioclesian's palace at Spalatro. Buildings of six sides were not common; but there is one at Balbec of peculiar form, two of the sides measuring 110 feet each, and the four remaining only 88 feet. There is also a curious circular temple at Balbec, of curious design; it is placed upon an octagonal base, the sides of which are curved inwardly, presenting a concave face; and at the angles of which are placed columns bearing an entablature, which is curved in a similar manner to the base.

We have alluded to the previous examples, for the purpose of showing how infinitely varied Roman edifices were in the arrangement of the main parts, and how readily a different distribution of the same or similar parts were made to exhibit a dissimilar effect. Many examples in proof of the same might be offered, were it within our limits to do so, and these on a more extensive scale, as witness the baths, fora, &c., with their many courts, saloons, galleries, and porticos, each of which might present some different method of distribution. It will thus be seen, how, in point of practical utility, the Romans took precedence of the Greeks, and how they were enabled to erect buildings suitable for any purposes which might be required. In such matters, they undoubtedly have the pre-eminence, but in matters of pure taste, they must be content to yield priority to the Greeks; for although in many cases they have shown proof of excellency of design, of which we need no other illustration than the Corinthian Order, which was fairly their own; yet at the same time, the generality of their designs do not exhibit that purity and simplicity which is the mark of true excellence. But besides this, many violations of true taste are constantly occurring even in their best works, indeed they seem to have been inherent in the system; amongst these, we may mention the inconsistent employment of the arch and entablature in the same design; and it is to be lamented, that instead of endeavouring vainly to unite the two systems, they had not struck out in a bolder course bv themselves, and worked out a consistent style of building. It is true that they employed the arch very freely, and sometimes probably more so than correct taste would warrant; yet at the same time they did not take that advantage of the possession of such means of construction as they might have done in a scientific point of view; they piled arch over arch, and seemed to be pleased with their acquisition, and content to make use of it, but not to apply it with any idea of improvement. But there are still one or two other points which merit reprehension, for instance, the employment of columns merely for the purpose of decoration, as where they are half inserted in the walls, or where pilasters supply their place. Now, columns are evidently intended for support, and they should always manifest such intention; and where they are used in positions where such support is not required, their employment is certainly objectionable, and would not be admitted in accordance with strict taste: the construction of ornament merely as ornament, and especially when its employment is liable to deceive, is to be condemned. A forcible illustration of the above kind is to be observed in triumphal arches, in which, although the columns be entirely isolated, and standing in front of the wall, they serve no practical purpose, their only use being to support a projecting portion of the entablature; and if it be asked for what purpose this projection is made, the most ready reply will be to give an useless column something to do. The fact is, that they are both added for the sake of effect, probably for variety in outline and for the sake of the deep shadow which such a projection would cast: but as far as construction goes, the whole thing is a sham, and deceptions in buildings indicate a low ebb of taste and science in architecture. Another characteristic of Roman art, and one which entered very largely into the system, is the employment of order above order in the same building, which illustrates at once its virtues and faults; for while on the one hand, such an arrangement is incompatible with the requirements of the highest standards of taste, yet still at the same time it proves their aptness of invention, and versatility of design.

We have now endeavoured to show in as fair a light as possible, the comparative merit of the two styles; and while, as a question of taste, we must without doubt yield the palm to Greece, we are inclined to think with Mr. Freeman, that architecture would have flourished more successfully at Rome, had she remained unacquainted with that of her rival.

Descriptions of some of the principal Roman buildings will be found in the body of this work; we may refer especially to the articles under the following heads :—Pantheon, Amphitheatre, Balbec, Palmyra, &c. The adaptation of the orders will be found noticed under Corinthian, Doric, Ionic, Roman, and Tuscan Orders.

ROMAN ORDER, an ordinance of architecture, invented by the Romans from the Ionic and Corinthian orders; and hence, it has also obtained the name of the Composite Order. *See* Order.

Vitruvius, the most ancient writer on architecture, after describing the three Grecian orders, mentions several fanciful compositions, without giving them any particular denomination. The name of *Composite order* is of modern application, and has been applied in consequence of the numerous examples to be found at Rome, and other parts of the ancient Roman territory, of an order compounded of the Ionic and Corinthian, which is of a very uniform character.

The capital of the Roman order is compounded of the Ionic and Corinthian, the upper part being the Ionic, and the lower the Corinthian. The entablature, as found in the ancient remains of Roman architecture, is Corinthian, and not one

example is to be found in the Roman antiquities as published by Desgodetz, but what have Corinthian entablatures.

The Composite order, as is to be found in several of the works of the principal Italian architects, has been compounded from the remains of the frontispiece of Nero, which is entirely Corinthian, and from the temple of Concord at Rome : the cornice is imitated from that of the frontispiece of Nero, which is the boldest, and one of the most beautiful remains of Roman grandeur. The upper part of the capital is taken from the temple of Concord, where the sides, or flanks, are the same as on the fronts, and project at every angle, the face of the abacus being concave ; and the two lower rows of leaves are what is usually found in any example of the Corinthian order ; but there is some little difference between the caulicoles, or stalks, that spring up between the leaves, which, though suitable to the composition, are not so elegant as in the Corinthian order.

It does not appear quite satisfactory to us why the examples included under this description, should be especially entitled to the term Roman, for the Corinthian has quite an equal claim ; they both owe their existence to the Romans. Why, indeed, any such marked distinction should be set up between the two, is not quite clear, for they are evidently but different modifications of the same idea ; and we think there can be discovered as much diversity in examples included under the term Corinthian, as between them and the Composite.

We subjoin a list, extracted from one of Mr. Weale's works, showing the proportions of the order in various examples.

	Base.			Column.			Capital.			Architrave.			Frieze.			Cornice.			Entablature.			Diam. of Column.	
	Diam.	Mod.	Ht.	Diam.	Mod.	Ht.	Diam.	Mod.	Ht.	Diam.	Mod.	Ht.	Diam.	Mod.	Ht.	Diam.	Mod.	Ht.	Diam.	Mod.	Ht.	Ft.	Inch.
Arch of Titus	0	0	23	10	0	6	1	0	$14\frac{1}{2}$	0	1	16	0	1	14	1	0	2	2	1	2	2	$10\frac{6}{12}$
Arch of Septimius Severus	0	0	20	9	1	10	1	0	$5\frac{1}{2}$	0	1	15	0	0	$25\frac{1}{2}$	1	0	$8\frac{1}{2}$	2	0	19	2	$0\frac{2}{10}$
Baths of Diocletian	0	0	20	10	0	$29\frac{3}{4}$	1	0	11	0	1	$14\frac{1}{2}$	0	1	14	0	1	21	2	0	$19\frac{1}{2}$	—	
Palladio	0	1	$1\frac{1}{2}$	10	0	0	1	0	0	0	1	10	0	1	4	0	1	20	2	0	0	—	
Scamozzi	0	1	0	9	1	15	1	0	0	0	1	9	0	1	$1\frac{1}{4}$	0	1	$16\frac{3}{4}$	1	1	27	—	
Vignola	0	1	0	10	0	0	1	0	0	0	1	15	0	1	15	1	0	0	2	1	0	—	
Caryatides of the Temple of Pandrosus	—			5	0	0	0	0	27	0	1	$25\frac{1}{2}$	0	1	0	1	0	0	1	1	$25\frac{1}{2}$	—	

The example of the Roman order which we have given, is from that exquisite remain of antiquity, the arch of Titus, at Rome.

ROMANESQUE ARCHITECTURE, a term applied to different purposes by various writers ; but the most useful and consistent application seems to include all the various kinds of building which originated from the Roman, and which appeared after the decline of art in that country, but with this limitation, that they still retain the semicircular arch. Under this general title, then, will be embraced the debased Roman, the Byzantine, Lombardic, Saxon, Norman, and the several varieties of the same class. For further information, *see* the above articles.

ROOD, a crucifix more especially applied to those which were placed in an elevated situation at the east end of churches between the nave and chancel. They were of large dimensions, and usually of wood, with figures of the Virgin and St. John placed on either side, and at the foot of the upright arm of the cross.

Rood Beam, a beam carried over the entrance to the chancel, for the purpose of supporting the rood.

Rood Loft, an elevated loft or gallery occupying a similar position to the rood-beam, but resting or appearing to rest on a screen below. It was usually spread out from the top of the screen on both sides of it, so as to give a landing at top of sufficient space for the rood-screen, and for the passage of persons to and fro. It was from this place that a part of the Romish service was performed. The soffit of the loft on either side of the screen, was either coved, or in the form of a semi-vault, with groining and ribs. The loft was approached by a staircase in the chancel-pier or main walls of the church, and these are frequently the only evidence of the existence of the loft.

Rood-Screen, the screen of open work which in most churches separated the nave and chancel ; the lower portion being panelled, and the upper perforated with rich tracery-work in the head. In the centre was a door, or pair of gates giving admission to the chancel. Such screens were usually of wood, but sometimes of stone, especially in cathedrals and larger churches ; they are also sometimes double ; as at St. David's Cathedral, and Gilden Morden, Cambridgeshire. Rood-screens, as well as the loft, and rood itself, were often of most elaborate workmanship, highly decorated with gilding and colour.

Rood Tower, the tower at the intersection of nave and transepts.

ROOF, (from the Saxon, *hrof,*) the cover, or top of a building, generally consisting of two sloping sides, though occasionally of other figures.

The ancient Egyptians, Babylonians, Persians, as well as other Eastern nations, had their roofs quite flat. The Greeks appear to have been the first who made roofs with a declination each way from the middle to the edges ; this was very gentle, the height from the ridge to the level of the walls not exceeding one-ninth or one-eighth part of the span, as may be seen by many ancient temples now remaining. In northern climates, subject to heavy rains and falls of snow, the ridge must be very considerably elevated. In most old buildings in Britain, the equilateral triangle seems to have been considered as the standard, both in private and public edifices ; and this pitch continued for several centuries, till the disuse of what is called Gothic architecture. The ridge was then made somewhat lower, the rafters being *three-fourths* of the breadth of the building. This was called *true pitch ;* but, subsequently, the *square* seems to have been considered as the true pitch. The heights of roofs were gradually depressed from the square to *one-third* of the width, and from that to *a fourth*, which is now a very general standard ; though they have even been executed much lower. There are some advantages in high-pitched roofs, as they discharge the rain with greater facility ; the snow continues a much shorter time on the surface, and they are less liable to be stripped by heavy winds. Low roofs require large slates, and the utmost care in execution ; but they have the advantage of being

much cheaper, since they require shorter timbers, and of a much less scantling. When executed with judgment, the roof is one of the principal ties to a building; as it binds the exterior walls to the interior, and to the partitions, which act like strong counterforts against them.

Roofs are of various forms, according to the nature of the plan, and the law of the horizontal and vertical sections. The most simple form of a roof is that which has only one row of timbers, arranged in an inclined plane, which throws the roof entirely to one side. This is called *a shed-roof*, or *lean-to*. The most elegant roof for a rectangular building, consists of two rectangular planes, of equal breadth, equally inclined, and terminating in a line parallel to the horizon; consequently, its form is that of a triangular prism, each side being equally inclined to the plane of the wall-head. This is sometimes called a *pent-roof*.

When the plan is a trapezium, and the wall-heads properly levelled, the roof cannot be executed in plane surfaces, so as to terminate in a level ridge. The sides, therefore, instead of being planes, are made to wind, in order to have the summit parallel to the horizon; but the most eligible method is to make the sides of the roof planes, enclosing a level space, or flat, in the form of a triangle, or trapezium, at the summit of the roof. Roofs flat on the top are said to be *truncated:* these are chiefly employed with a view to diminish the height, so as not to predominate over that of the walls.

When all the four sides of the roof are formed by inclined planes, it is said to be *hipped*, and is, therefore, called a *hipped-roof;* and the inclined ridges springing from the angles of the walls are called *hips*. Roofs of this description are frequently truncated; and when the plan of the walls is in the form of a trapezium, the truncation of the roof becomes necessary.

Roofs upon circular bases, with all their horizontal sections circular, the centres of the circles being in a straight line drawn from the centre of the base perpendicular to the horizon, are called *revolved-roofs*, or *roofs of revolution*.

When the plan of the roof is a regular polygon, or a circle, or an ellipsis, the horizontal sections being all similar to the base, and the vertical section a portion of any curve convex on the outside, the roof is called *a dome*.

To save the expense of lead in the roofs of rectangular buildings, instead of the flat, a valley is sometimes used, which makes the vertical section in the form of the letter M, or rather an inverted W; and hence it has obtained the name of *an M roof*.

Definitions.—In order to be understood by the reader, it will be necessary to explain such terms as are used in the subsequent part of the article, by way of definitions.

Wall-plates, pieces of timber laid on the wall, in order to distribute the pressure of the roof equally, and to bind the walls together. They are sometimes called *raising-plates*.

Trusses, strong frames of carpentry, generally of a triangular form, supporting the covering. They are disposed at equal distances, and are used when the expansion of the walls is too great to admit of common rafters alone, which would be in danger of being bent or broken by the weight of the covering, for the want of some intermediate support. They are variously constructed, according to the width of the building, the contour of the roof, and the circumstances of walling below, &c.

Tie, any piece of timber connected at its extremities to two others, acted upon by opposite pressures, which have a tendency from each other; or, to extend the tie, as a rope or chain.

Straining-piece, a piece of timber, connected at its extremities to two others, acted upon by opposite pressures, which have a tendency towards each other.

Hence, a tie acts contrary to a straining-piece. A chain, rope, or small bar of iron, may be used for the former; but the latter must always be inflexible, being in a state of compression.

Principal rafters, two pieces of timber in the sides of a truss, supporting a grated frame of timber-work over them, on which the slating or covering rests.

Purlins, horizontal pieces of timber fixed upon the principal rafters.

Tie-beam, a horizontal piece of timber, connected to two opposite principal rafters. It answers a twofold purpose, viz., that of preventing the walls from being pushed outwards by the weight of the covering, and of supporting the ceiling of the rooms below. When placed above the bottom of the rafters, it is called *a collar-beam*.

Common rafters, pieces of timber of a small section, placed equidistantly upon the purlins, and parallel to the principal rafters: they support the boarding to which the slating is fixed.

Pole-plates, pieces of timber resting on the ends of the tie-beams, and supporting the lower ends of the common rafters.

King-posts, an upright piece of timber in the middle of a truss, framed at the upper end into the principal rafters, and at the lower end into the tie-beam: this prevents the tie-beam from sinking in the middle.

Queen-posts, two upright pieces of timber framed below into the tie-beam, and above into the principal rafters, placed equidistantly from the middle of the truss, or its extremities.

Struts, oblique straining-pieces, framed below into the king-posts or queen-posts, and above into the principal rafters, which are supported by them; or sometimes they have their upper ends framed into beams, which are too long to support themselves without bending. They are often called *braces*.

Puncheons, short transverse pieces of timber fixed between two others for supporting them equally, so that when any force operates on the one, the other resists it equally; and if one break, the other will also break. These are sometimes called *studs*.

Straining-beam, a piece of timber placed between two queen-posts at the upper ends, in order to withstand the thrust of the principal rafters.

Straining-sill, a piece of timber placed at the bottom of two queen-posts, upon the tie-beam, in order to withstand the force of the braces, which are acted upon by the weight of the covering.

Camber-beams, horizontal pieces of timber, made on the upper edge, sloping from the middle towards each end, in an obtuse angle, for discharging the water. They are placed above the straining-beam in a truncated roof, for fixing the boarding on which the lead is laid; their ends run three or four inches above the sloping plain of the common rafters, in order to form a roll for fixing the lead.

Auxiliary rafters, pieces of timber framed in the same vertical plane with the principal rafters, under and parallel to them, for giving additional support, when the extent of the building requires their introduction. They are sometimes called *principal braces* and sometimes *cushion-rafters*.

Joggles, the joints at the meeting of struts with king-posts, queen-posts, or principal rafters; or, at the meeting of principal rafters with king and queen-posts: the best form is that which is at right angles to the struts.

Cocking, or *cogging*, the particular manner of fixing the tie-beams to the wall-plates: one method is by dove-tailing,

the other is by notching the under side of the tie-beam, and cutting the wall-plate in a reverse form to fit it. This method is far preferable to the other, as it is not liable to be drawn, which the other is very subject to when the timber shrinks.

Ridge-tree, a piece of timber fixed in the vertex of a roof, where the common rafters meet on each side of it; the upper edge of it is higher than the rafters, for the purpose of fixing the lead which goes over it to cover the ends of the slates in the upper course.

Straps, thin pieces of iron running across the junction of two or more parts of a truss, or frame of carpentry, branching out from the intersection in the direction of the several pieces, for the purpose of securing them to each other. They ought always to be double, viz., one strap on each side, and their ends strongly bolted to each of the pieces.

The uses of these various parts will be illustrated in what follows; and here, it may be proper to observe, that though every one of the parts above defined *may* be found in the same roof, it is not necessary that a complete roof should have them all; the introduction of many of them depends on the distance of the walls, the contour of the roof, the partitions below, the quantity of head-room wanted in the garrets, &c.

Other names of timbers will be fully illustrated in the descriptions of other roofs, in due order of succession.

Before we proceed to the construction of roofing, it will be necessary to show upon what principles a body, or piece of timber, may be supported in various positions.

Proposition I. *Plate* I. (*of Mechanical Carpentry*) *Figure* 1.—*If a heavy body*, A B C D, *be suspended by any two inclined strings*, D E *and* C F, *in a vertical plane, a right line drawn through the intersection, perpendicular to the horizon, will pass through the centre of gravity of the body.*

It is shown by the writers on mechanics, that if any three forces act upon a point, or a body, their directions will tend to the same point, or be parallel to each other. It is well known that every body acts with its full force in one point only, viz., its centre of gravity, and in a direction perpendicular to the horizon: therefore, if a body be sustained at E and F, it will revolve round these points, till the line, G H, passing through the intersection, H, of the two strings, D E and C F, and the centre of gravity, G, becomes perpendicular to the horizon.

Corollary 1.—Hence, if any body be supported by two strings, it may also be supported by two planes perpendicular to those strings, provided the two points of the body supported be in the direction of the strings; for every body acting upon a plane acts in a line perpendicular to that plane.

Corollary 2.—Hence, also, a body may be supported by two props in any two directions that it may be supported by strings, provided the surface of the body, at the points of contact, or the ends of the props, be planes, at right angles to the strings.

Corollary 3.—Hence, all the properties that have been demonstrated of three forces acting upon a body supposed to be void of weight, will equally flow from a heavy body supported by two strings, by substituting the weight of the body for the middle force; and hence, if the direction of any force supporting a heavy body be given, the other may easily be found.

Proposition II.—*Given the position in which a body should be placed, and the position of a plane supporting the body at one end; to find the position of another plane to support it at another given point, and to find the pressure on the planes, the weight of the body being given.*

Through the centre of gravity of the body draw a vertical line, and through any point on which the body rests on the given plane, draw a line perpendicular to that plane, meeting the vertical line: from the intersection draw a line to the other point, which is to be supported; from that point draw a plane at right angles to this line, which will be the direction of the plane required.

To find the intensity of the forces, take any distance on the vertical line, to represent the weight of the beam, from the intersection; on that line, as a diagonal, complete a parallelogram, whose sides are in the directions of the lines perpendicular to the supporting planes; and the side of the parallelogram, perpendicular to either plane, will represent the force on that plane.

Example 1. *Figure* 2.—Let the body, A B C D, lie upon the top of the wall, K C at C, so as to touch the lower edge, B C, of the body, at that point, C; it is required to find the direction of a plane that will support the lower end at B, and to find the pressure of the body on the wall and on the plane.

Through the centre of gravity, G, of the body, draw the vertical line G F; draw C F perpendicular to C B; join F B, and draw B I perpendicular to F B; and B I will be the direction of the plane required. On the vertical line, G F, make F M to represent the weight of the body, and complete the parallelogram L M N F; then F N will represent the force on the wall-head, in the direction F C; and F L the force acting perpendicular to the plane, or in the direction B F. But if the vertical and horizontal thrusts on the wall at C be required, draw N P perpendicular to F G, meeting it in P; then the force, F N, will be resolved into two forces, F P and P N. P N will represent the horizontal part of the force, viz., that which pushes the wall in a direction parallel to the horizon; and F P the other part, which tends to press it downwards in a direction perpendicular to the horizon.

Example 2. *Figure* 3.—Let the sloping body, A B C D, be supported by a wall at its lower end, D, which coincides with the surface of the body, and let G be the centre of gravity; it is required to cut a notch out of the body, at the upper end, C, so that it may rest upon the top of a wall, which is made to fit the notch, and to find the pressure on the walls.

Draw the vertical line, G E; from D draw D E perpendicular to D C; join E C, and make C F at right angles to it; then, the notch H C F being cut, the body, A B C D, will be at rest. To find the pressure on the walls, complete the parallelogram, E I K L, having a given angle, D E C, and its diagonal on the given line, E G; then, if K E represent the weight of the body, I E will represent the pressure in the direction D E, upon the wall at D, and L D the pressure in the direction C E, The horizontal and perpendicular pressures upon each wall may be found, as in the preceding example, by resolving each of the forces I E and L E, into two; one of which is perpendicular to the horizon, and the other parallel to it.

Scholium.—It must be observed in this example, that the notch, which is cut out at C, will remove the centre of gravity nearer to the lower end, D, and consequently alter the slope, C F; but as this can only be in a very small degree, the equilibrium will hardly be affected by it, when the notch is very small.

Example 3. *Figure* 4.—Let one of the corners of a sloping body, A B C D, rest upon the top of a wall at D, which is quite level: it is required to find the position of a notch, cut out of the upper end, C, so that the body may rest upon a wall made to fit the notch.

Let the small part, F C H, be so cut that C H may be parallel to the horizon, then the body will be supported by the two walls at C and D. For, draw D I, G K, and C L perpendicular

to the horizon, these lines being produced, they may be supposed to meet at an infinite distance. To find the pressure on the walls: join D C, and produce the vertical line, K G, to meet it in E; then, if G be supposed to be the weight of the body, the pressure on D will be $\frac{EC \times G}{DC}$, and the pressure on C $= \frac{DE \times G}{DC}$.

Example 4. *Figure* 5.—Let the body, A B C D, lie with its upper end against the vertical face of a wall at C; it is required to find the position of a plane supporting the lower end, D, so that the body may be at rest.

Draw the vertical line G E; also C E perpendicular to the face of the wall, C L; join E D, and draw D F perpendicular to E D; then D F will be the position of the plane required. Complete the parallelogram, E H I K; then the pressure on D and on C, and the weight of the body, will be to each other as E H, E K, E I.

Example 5. *Figure* 6.—To support a body, A B C D, by two props at two given points, E and I, the direction of one of the props, E F, being given:

Draw the vertical line, G K; produce F E to K; draw K I H; and I H will be the prop required. On the vertical line, G K, take K M to represent the weight of the body; and on K M, as a diagonal, describe the parallelogram, K L M N; then K L will be the compression of the prop E F, and K N the compression of the prop I H.

Construction.—*Plate* II. *Figure* 1.—Of common roofs, the simplest construction is that which consists of two rafters, as A B and B C; D and E are wall-plates, on which the feet, A and C, of the rafters rest; the bottoms of the rafters are cut in the form of a right angle (called by the workmen *a bird's mouth*) reversed to the wall-plate, and are fixed to it with nails; but this form can only be applied to buildings that have their walls at no great distance from each other.

Figure 2.—The next form is that of having two rafters, as A B, B C, a collar-beam, D E, with two wall-plates, F and G, below. This form will admit of a greater distance between the walls than the other: the beam is placed in the situation D E, in order to give head-room within; but when the span, F G, of the walls is considerable, the parts A D and C E being considered as levers, and acted upon by the reaction of the walls, the rafters are either liable to be broken at the points D and E, or curved with a concavity on the upper edges.

Figure 3.—The third form of common roofs consists of two rafters, A B, B C; a tie-beam, A C, for preventing the rafters from pushing out the walls; a collar, or straining-beam, D E, and two puncheons, or studs, F G and H I, for keeping the rafters straight; this construction is used for cheapness, and may be executed with safety in houses not exceeding 45 feet wide; but it is necessary to have partitions immediately below, or at no great distance from the studs. Instead of supporting every opposite pair of rafters, as in this example, it happens, in many roofs of this construction, that the rafters take the place of principals, and are fixed at 7, 8, 9 or 10 feet from each other; while purlins run over the heads of the puncheons at K and L; and, at the ends of the collar-beams, at M and N, between every two rafters, smaller rafters are fixed to the purlins, the wall-plates at bottom, and the ridge-tree at the top.

Figure 4.—The most simple construction of a truss consists of the following parts:—A B the tie-beam, cocked upon the wall-plates, C and D; E K the king-post; A G and B H principal rafters, fixed to the king-post at the joggles, G and H; L M and N O struts, mortised into the rafters at L and N, and joggled to the king-post at M and O.

Proposition III.—*In any roof constructed with two equal rafters only; as the height of the roof is to half the breadth of the building, so is half the weight of the roof to the horizontal thrust, or lateral pressure.*

Figure 5.—Let A B C be a roof, having the two equal rafters, A B, B C; join the bottom of the rafters, A C; draw B D perpendicular to it; complete the parallelogram B E F G, and draw E G, cutting B D in H. Then, because the triangles, B H E and B D A are similar,

B D : D A : : B H : H E.

Corollary 1.—Hence, in a roof with two rafters and a tie-beam at the bottom, the tension, H E, of the tie-beam is $= \frac{DA \times BH.}{BD}$

Corollary 2.—Hence, also, B D : B A : : B H : B E; that is, as the height of the roof is to the length of the rafter, so is half the weight of the roof, represented by B H, to the compression of the rafters $= \frac{BA \times BH.}{BD}$

Corollary 3.—Half the weight of the roof, the tension of the tie-beam, and the compression of the rafters, are to each other as the height of the roof, half the breadth of the span, and the length of the rafters; for the triangle B H E is similar to the triangle B D A.

Proposition IV.—*If a rafter bear any weight, or have a weight uniformly diffused over it, the force tending to break it is equal to the cosine of elevation multiplied into the weight, divided by radius.*

Figure 6.—Let A B, B C, be two equal rafters; join A C, draw B G perpendicular to it meeting it in G; and let the weight w be suspended by the string D E. Draw D F perpendicular to A B, and E F parallel to it; then, if D E represent the weight, D F will represent the force tending to break the rafter; and E E its tendency to push it from B towards A.

Now because E F is parallel to A B, the alternate angles A D E and D E F are equal, and the angles D F E and A G B are right angles; the triangles E D F and B A G are similar; therefore A B : A G : : D E : D F $= \frac{AG \times DE}{AB}$; but if A G be made the radius, then D E will be the cosine of elevation; therefore R : cos' elevation : : D E : D F $= \frac{\text{cos' elevation} \times DE}{R}$

Corollary 1.—Hence the weight employed, the pressure in a direction of the length of a rafter at A, the tendency to break it, are as radius, the sine, and cosine of elevation.

Corollary 2.—Because D F $= \frac{\text{cos' elevation} \times DE}{R}$, and because the stress is as the length, when the weight is given, the stress is as the cosine of elevation multiplied into the weight, and this product multiplied into the length of the rafter; the radius being a constant quantity.

Proposition V.—*To prevent the rafters of a roof, with a tie-beam, from bending in the middle, and to remove lateral pressure from the walls, when there is no beam.*

A variety of methods may be used for this purpose; but the best are those in which the shortest and least quantity of timber are employed, without producing a transverse strain upon any part. When a roof consists of two rafters only, no part of the rafters can be loaded between their extremities; nor indeed will they bear their own weight without producing a concavity on the upper side, which will be greater as the length of the rafter and weight applied to it are greater. Now, because the shorter the rafters are at the same elevation, the greater weight they will bear, and be more able to support their own weight; the object is to support them by

a sufficient number of fixed points, either from the roof itself, or from other immoveable places. There are three points for this purpose; if the rafters have a tie-beam below, that is, at the vertex, and at the two extremities of the rafters, the triangle being immoveable at the angles, every force applied there tends either to compress or extend the sides of the frame, without a transverse strain.

Examples.—Let it be required to divide each of the rafters into three equal lengths, in order to support two purlins on each side; this may be done, as in *Plate* III. *Figure* 1, by pieces, C E, C D, A G, A F, reaching from the two lower angles, C and A, and to the opposite sides of the rafters, A B and B C, intersecting each other at H and I, and halved upon each other at these intersections: this mode prevents the rafters from sagging, but does not afford any support to the tie-beam. The meeting of so many braces at the same point, too, gives little opportunity of making the ends entirely secure, even though assisted by iron straps.

Another mode may be by introducing a king-post, B K, *Figure* 2, to which the struts, D H, E I, F M, G L, may be firmly joggled at H, I, M, L, and mortised to the rafters at D, E, F, G: this method keeps up the middle of the beam; but when the roof is low, and the span great, the struts, D H and F M, require themselves to be supported, and are much too oblique to prevent a change of figure.

Another method may be, as in *Figure* 3, with the king-post in the middle, as before, two queen-posts under the rafters at E and F, two struts, H E and I F, joggled to the bottom of the king-post at H and I, and to the top of the queen-posts at E and F; and in order to secure the points N and P, two other braces, N Q, P R, are joggled to the bottom of the queen-posts at Q and R, and mortised into the rafters at the upper end. This construction supports the tie-beam in three different points, and each of the rafters in two. The timbers are much shorter than those of the preceding; but so many joggles are certainly an objection to this method, as the shrinking of the timber must be very considerable in three breadths, which would allow the roof to descend.

When the span is great, and the points to be supported many, an excellent method may be as in *Figure* 4, where there are two arches of cast-iron, or good English oak, introduced, which abut on the king-post, and at the other extremity at the ends of the beam. The rafters and the beam, by this mode, may be supported by as many equidistant points as we please.

When the tie-beam is removed from the bottom, as in *Figure* 5, and no fixed points are to be found from below, a longitudinal truss may be constructed, the end of which is shown at A B, and the manner of framing it in *Figure* 6, the two ends being supposed to be firmly fixed into the gables; but where the length is great, the form of *Figure* 7, with a parabolic arch, would be much better: by this method, the rafters will be kept nearly in the same plane, and all lateral pressure from the walls will be removed; for it is evident that if the ridge-tree is supported, there can be no motion downwards in the direction of the rafters, the whole roof being hung to this longitudinal frame.

PROPOSITION VI.—*Figure* 8.—If a roof be constructed with two equal rafters, A M, C M, with a tie extending from the bottom of each to an intermediate point in the opposite rafter, and the ties halved together at their intersection, B, so as to form with the rafters a quadrilateral, M D B E, at the vertex, and two triangles, A D B and C E B; then, if M D be equal to M E, and C P represent the direction and quantity of force on the wall at C, the force tending to break the rafters at D and E is $\frac{\text{S. P C K} \times \text{S. D M E} \times \text{L K} \times \text{D M}}{\text{S. L C K} \times \text{R}}$.

For completing the parallelogram P C L K; making M N equal to C L; and N O parallel, and M O perpendicular to A M, the triangles C B E and A B D may be looked upon as solid levers (at least with regard to forces applied to the angles) moveable round B. Then the force C P will communicate the force C L to the rafter, and C L is the power acting obliquely at M upon the rafter A M: then because N O is parallel, and O M perpendicular to A M, O M is the force tending to break the rafter at D, and O N that pushing it towards A: therefore, let M N be considered radius, and O M will be the sine of the angle D M N, or D M E; for produce A M to Q, and the angle N M Q will be the supplement of the vertical angle D M E; therefore the sine of N M Q, equal to the sine of the angle M N O, is the same with the sine of N M A; then by trigonometry,

L K : L C : : S. L C K : S. C K L or S. P C K
N M or L C : M O : : R : S. D M E = S. M N O;
therefore, L K : M O : : S. L C K × R : S. P C K × S. D M E.

Hence $\text{M O} = \frac{\text{S. P C K} \times \text{S. D M E} \times \text{L K}}{\text{S. L C K} \times \text{R}}$ = the force acting perpendicular to A M at M; but the force tending to break the rafter at D is as the lever D M multiplied into this force; that is $= \frac{\text{S. P C K} \times \text{S. D M E} \times \text{L K} \times \text{D M}}{\text{S. L C K} \times \text{R}}$.

Corollary 1.—Hence, if the angle D M E is a right angle, the force tending to break the rafter at D will be $\frac{\text{S. P C K} \times \text{L K} \times \text{D M}}{\text{S. L C K}}$.

Corollary 2.—Hence the rafters of every roof of this construction must sag in a greater or less degree, by the action of the rafters against each other at the point M; that is, they will be bent into curves concave on the upper edges; but if a diagonal connect the two vertical points M and B, this change of figure will be prevented.

PROPOSITION VII.—*To remove the lateral pressure of a roof without any intermediate beam, brace, or strut.*

Plate IV. *Figure* 1. No. 2.—Let A B, B C, be two rafters, and let there be constructed a strong wall-plate, D E F G, No. 1, firmly bolted together at the angles; then if the roof is to be gable-ended, after having fixed the rafters to a common ridge-tree, let two curves be made of cast-iron or good English oak, of a parabolic form, and let into the rafters, either on the upper or under surface, and firmly secured to them by bolts or nails, and at their lower extremities to the angles of the wall-plates, the vertex of each curve meeting the ridge-piece on each side of it or nearly so, as may be convenient. One half of the plan, No. 1, exhibits the form for the execution of a gable-ended roof, and the other for a hipped-roof. The two sides, laid in plano for each form, are shown in No. 3 and No. 4; at H I K L and M N O P, H L and D G represent the same wall-plate; D G, N O, and E F another wall-plate, I K and M P meeting the ridge on each side of it: but it must be observed when the roof is to be hipped, that the ridge-tree must be very strong, as the compressure will be very great, the hip-rafters acting like powerful braces at its extremities. Hence it is evident that the wall-plates act as the tie-beams of a common roof, and the curves as the rafters; or, more naturally, like an arch of a bridge in equilibrio. It has already been shown that equal weights, acting in equidistant lines, require an arch of a parabolic form to keep them in equilibrio. In this it is to be considered, that as the arches are placed with their crown upwards, they are in a state of compression, and may be got out very conveniently in several lengths; but if the arches were inverted, they would be in a state of tension; each arch must then be in one piece, as the ridge would be compressed

by the tension of the two curves. This inverted disposition of equilibration is not so secure as when the crown of the arches either meets the ridge or lies towards it.

Though the above construction will prevent lateral pressure, it will not hinder the rafters from sagging; but the addition of a collar-beam will effectually answer this purpose in all moderate spans.

PROPOSITION VIII.—*Given the construction of a roof, of which not more than three timbers meet at the same junction, and a force in the direction of any one of the timbers; to find the forces communicated to the other timbers, so that the roof shall be in equilibrio.*

Begin with the given force, and take a part of the line of its direction from the junction to represent it; then, with the other two directions, complete a parallelogram, and apply them from the next junctions on the same straight line from which they were taken, and complete parallelograms, as before. Proceed in this manner, from one junction to another, until parallelograms have been made at every one. Then the parts of these parallelograms, in the directions of the timbers, are the forces in these directions; and to ascertain the state of tension or compression of any timber, observe that when two of the angles formed by three directions are less than two right angles, the middle force acts always contrary to the two extreme ones, as has already been explained; and that when any two of the angles of direction are greater than two right angles, then the forces will act towards or from the same point.

Example 1.—*Figure* 2.—Let A B C D A be a roof, consisting of two rafters, A B, B C, two beams, C D, D A, and a king-post, D B, supported by the walls A O and C E. Let C E represent half the weight of the roof, or the reaction of the wall, C E; complete the parallelogram C E F G; make D L equal to F C, and complete the parallelogram L M N D; then C F, or D L, is the force in the direction of the beam C D, or A D, and D M is the force in the direction of the post D B; now, because the angles E F C and F C G are less than two right angles, and because the point C is pressed by the reaction of the wall E C, it will also be pressed by the force G C, and drawn by the force C F; therefore the beam C D is in a state of tension, and the rafter B C in a state of compression. Again, because C D B and B D A are greater than the two right angles, and because C D is in a state of tension, B D and D A are also in a state of tension.

If B H be made equal to G C, and the parallelogram B H I K completed, and if B P be made equal to D M, then will P I be equal to twice C E, the pressure on the walls.

Example 2.—*Figure* 3.—Let A B C D E A be a roof, supported by walls in the directions P A and Q C, and let there be two pieces of timber, B D and B E, connecting the angular points, D and E, to the ridge at B.

Take C F to represent half the weight of the roof, or the reaction of the wall Q C: complete the parallelogram C F G H; produce C D to K; make D K equal to G C, and complete the parallelogram D I K L; then G C, or D K, is the force in the direction of the timber C D or A E, and is in a state of tension, because the angles F C G and G C H are less than two right angles, and because C F is in a state of compression; C H, the force in a direction of the rafter B C, is also in a state of compression; and because any two of the three angles, G D B, G D E, E D B, are greater than two right angles, and D C is in a state of tension, the two pieces, D B and D E, are also in a state of tension; that is, E A, E B, E D, D B, D C, are all ties. The force in D B or E B is D L, that in D E is D I.

If B R and B S be made equal to C H, and the parallelogram B R W S completed; and if B T and B U be made equal to L D, and the parallelogram B T V U completed, then will V W be equal to twice C F; that is, by reducing the force in the direction of the pieces B E and B D to an equivalent one.

PROPOSITION IX.—*Given the lengths* A B, B C, C D, D E, *of the rafters of a roof and their angles of position, to find those angles that require ties, and those which require struts.*

Plate V. *Figure* 1.—Let A B be to B C as 3 to 4, that is, as 6 to 8, the proportion of the weight of the rafters; then if 8 be taken for the weight of each of the upper rafters, $\frac{8+8}{2} = 8$ will be the weight on the vertical angle C, and $\frac{6+8}{2} = 7$, will be the stress on each of the vertical angles B and D, so that the weight on the vertical angle is to that on each of the lower angles, as 8 to 7. Draw the vertical line B G F, and draw A G, A F, parallel to the rafters B C, C D; then if F G be to G B as 8 to 7, the rafters will be in equilibrio, and require no ties. But suppose it should be found that F G is to G B as 1 to 2; as that will keep it in equilibrio, it would require a very considerable addition laid on the angle, B, to keep it from springing outward, so that if two braces, F G and K L, No 2, were fixed to the rafters, A B, B C, C D, D E, these would be in a state of compression; and if the brace, H I, were fixed at the top, it would be in a state of tension: F G and K L only require firm butments, but H I to be well bolted. It may here be observed, that if the vertical angle only be braced and secured to the two rafters, the whole frame will then be immoveable.

PROPOSITION X.—*To discover the effect of bracing the angles of a roof flat on the top, supported by puncheons at the bottom of the rafters, to accommodate a semicircular ceiling within.*

Figure 2. No. 1.—Let A B C D E F be the truss, divested of its braces, the bottoms of the puncheons resting firmly on the walls at A and F, and the joints at B, C, D, E, to be quite moveable, like rule-joints. Now, as this disposition of timbers would fall, and in falling, would assume the form of No. 2, the angles at C and D would become more and more obtuse, while those at A and E would, in the same proportion, become acute; the latter would, therefore, require straining-pieces, and the former ties; the straining-pieces must have good abutments, and the ties must be well bolted at their extremities.

Let No. 3 be the truss, with braces disposed in the lower angles; this disposition will bend the rafters B C, D E, and the puncheons, B A, E F, convex towards the outside, which is entirely occasioned by the braces, G H, N O: the camber-beam, C D, is no otherwise affected than by its own weight. Let it now be supposed, that the angles C and D, No. 4, are braced at I K, L M. In this disposition, the puncheons, B A, E F, are not affected in respect of transverse strains; the rafters C B, D E, and the beam C D, would all become concave on the outside; and the points B and E, at the bottom of the rafters and top of the puncheons, would be pushed out beyond the perpendicular of A and F, at the bottom: here it is necessary to observe that the effect produced in this case on the rafters C B and D E is contrary to the effect produced in No. 3, by the braces being disposed in the lower angles. Lastly, suppose that all the angles are braced, as in No. 5, it is evident, since the braces, H G, N O, produce a contrary effect to the braces K I, L M, these bending the rafters downwards, and those upwards, that the rafters C B and D E will become nearly straight, or assume an undulated line: the puncheons B A and E F, receiving the force of the braces H G and N O at the points G and O, must still be bent, so long as the under ends, G and O, of the braces do not coincide with the under ends, A and E, of the puncheons: in this case, there

is no other remedy than by giving the puncheons a scantling sufficient to withstand this transverse strain, or horizontal thrust, at the points G and O; however, the shape of the contour may be pretty well secured by introducing two abutments, H I and M N, No. 6; these by being bolted through the two ends, will add greatly to the stiffness of the rafters B C and D E; the bolts that go through the upper ends may also serve for the braces I K and L M: the shape of the horizontal beam, C D, will likewise be very much preserved by the piece K L, bolted in three places, one at each end, into the braces I K and L M, and another in the middle: the contour of a roof, thus supported, would be quite unchangeable, if the rafters were inflexible; but, as this is not the case, and as they are acted upon transversely by the braces, the truss will therefore, in some degree, be expanded at B and E, and consequently occasion lateral pressure on the walls; it will, therefore, be unfit for an oblong building, without other precautions for this purpose. By inserting parabolic curves in the sides B C and D E, as in *Plate* IV. *Figure* 1, it will be effectually prevented.

In roofs of this description, joggle-pieces of wood should never be used, as their shrinking would tend greatly to alter the outline of the rafters.

Having laid down such principles as will enable the workman to judge of the strength and strain of timbers in the framings of carpentry, it will now be necessary to proceed to show the mode of constructing roofs to answer various purposes; to give some practical observations relative to their strength, and to show the various modes of joining timbers, the forms of traps, &c.

As we have above stated, the simplest form of a perfect trussed roof, consists of two principal rafters inclined to each other, and meeting at the apex, the lower ends being tied together by a horizontal tie-beam, to prevent their spreading and thrusting out the walls upon which they are supported. As, however, the gravity of this tie-beam, especially if of any considerable length, is apt to cause it to sag in the centre, between the bearings, it is necessary to provide another bearing for it between the walls, and this is effected by suspending it in the centre by means of what is termed a *king-post*, which, in its turn, is held up between the principal rafters at the apex of the roof. To assist in effecting the same object, the tie-beam is sometimes cambered or arched, but this plan can scarcely be recommended, for if the timbers settle, as in all probability they will do, the cambered beam being extended into a straight one is liable to push out the walls, and cause the mischief which it was intended to prevent. The better plan is, to camber the beam only on the upper side, the lower side being horizontal, so as to have the greater scantling in the centre; this plan, however, is not without objection, for by it you have the greater weight at the centre, where it is most effective to cause the beam to sag. To afford the same assistance to the principals, and to prevent their sagging by their own weight and that of the covering which they have to support, short struts are carried from their centre to the foot of the king-post on either side of it, and on this they have their support. In a truss of this kind we have the tie-beam and king-post in a state of tension, while the principals and struts are subject to compression. Roofs of this class are very common, and are adapted for buildings where the span is not above 30 or 35 feet.

When the span gets beyond this, it is necessary to suspend the tie-beam at more points, and first of all, at two where the extreme bearings are not much more distant. In this case two suspenders, termed *queen-posts*, are employed, holding up the tie-beam at two points equidistant from each other and from the walls of the building; the principals are not extended to meet each other at the apex, but terminate at the queen-posts against which they abut, and the queen-posts are retained at the required distance from each other by means of a *straining beam*, which also abuts against the head of the queen-posts, and by this means they are suspended. This description of truss is something like the first, if we suppose the king-post separated into two halves, with a horizontal strut placed between them, to prevent the principals from being pressed together; struts are also placed at the foot of the queen-posts, to support the principals.

A truss for a still greater span is formed by suspending the tie-beam at three intermediate points, having a king-post between two queen-posts, without a straining-beam, the principals being carried to meet each other at the apex, as in the first description of roof; struts are carried from the foot of the king-post to the head of the queen-posts, and from the foot of the queen-posts to the principals. In many cases a roof with the same number of suspenders is somewhat differently constructed, and this consists, in the first place, of a roof precisely similar to the second above described, having, however, in addition, a king-post in the centre, carried up through and above the straining-beam, which is divided into two lengths, and abuts against the king-post on either side. Above and parallel to the principals is placed another pair of principals, which are continued to meet at the apex, where they abut against the king-post; these alone are termed principals, the other subordinate rafters which abut against the queen-posts, being termed *straining braces*, or *auxiliary rafters*. The principals are further supported at the upper part by struts, which spring from the king-post above the straining-beam, and below by a continuous bearing on the straining-braces, which, in their turn, are supported by the struts from the foot of the queen-posts. The last form of roof is calculated for a span of 60 to 80 feet, and the previous one for a span of 50 or 60 feet. Sometimes, instead of a single king-post, this kind of truss will have the king-post, as it were, split in half and hung on either side of the truss, from the heads of the upper principals, extending down to the tie-beam; in this case the straining or collar beam is in one piece, and passes between the halves of the king-post. Another variation consists in splitting the truss into two half-trusses, and keeping the king-post between them both, so as to form one mass. A roof of this kind was constructed over the basilica of St. Paul at Rome more than four centuries ago.

This expedient may be entirely obviated by the use of iron king-posts, which, in all cases, would seem preferable to those of wood, both for king or queen-posts, or, indeed, for any member of the truss which is subjected to tension, as for ties, where its employment, to a very considerable extent, obviates the difficulty which is experienced by the sagging of tie-beams of timber. The number of suspenders, especially if composed of iron-rods, may be still further extended to seven or eight, or, indeed, any number, the only limit being found in the length of the principals.

For the strength of different materials the reader may consult the article on that subject, but as a general remark it may be observed, that oak when exposed to tension is weaker than fir, and is therefore less adapted for ties. Being, however, less compressible, it is usually preferred for rafters, straining-pieces, and struts; but Tredgold observes, that its greater tendency to warping in summer renders it less fit for rafters and purlins than foreign fir. Cast-iron is not much used, except in fire-proof roofs, and each piece requires to be well tested. Wrought-iron is very useful for straps and also for ties and trussing-posts; but care is always necessary to guard against imperfections, which are more likely to pass unobserved than in wood. Wherever iron is applied, pro

vision should be made for its expansion and contraction, and it is desirable to protect it from oxidation by painting. Though iron is far stronger for its size than any kind of timber, it is neither so strong nor so cheap as yellow-fir, *weight for weight*.

Plate VI. *Figure* 1, is the roof of the chapel of the royal hospital at Greenwich, constructed by Mr. S. Wyatt.

It is constructed with two queen-posts, and is similar to the second kind of roof above described, but it has in addition two struts from the foot of the queen-posts to the straining-beam, which abut against a second straining-piece underneath the first; the tie-beam is also further suspended from the straining-beam by an iron-rod, which answers the purpose of a queen-post.

The following are the scantlings of the various timbers :—

		Inches Scantling.
AA,	The tie-beam, 57 feet long, the span of the walls being 51 feet	14 × 12
B,	Queen-posts	9 × 12
C,	Braces	9 × 7
D,	Straining-beam	10 × 7
E,	Straining-piece	6 × 7
F,	Principal rafters	10 × 7
G,	Camber-beam, for the platform.	9 × 7
H,	An iron rod, supporting the tie-beam	2 × 2

The trusses are seven feet clear; the platform is covered with lead, which is supported by horizontal beams six by four inches.

The timbers of this truss are well disposed, and perhaps contain less wood than most roofs of the same dimensions.

Figure 2 is the roof of St. Paul's, Covent-Garden, designed by Mr. Hardwick, and constructed by Mr. Wapshot in 1796.

This roof, although of the same general construction as the last, varies from it in several particulars. The lower portion is precisely the same as the second class of truss, but in addition there is a second pair of principals, which are supported on the lower by studs, and the lower principals thus becoming only auxiliaries; the queen-posts are continued up to the principals, and a king-post is carried from the apex to the straining-beam.

The scantlings are :—

		Inches Scantling.
AA,	The tie-beam, spanning 50 feet 2 inches	16 × 12
B,	Queen-posts	9 × 8
C,	Straining-beam	10 × 8
D,	King-post, 14 inches at the joggle	9 × 8
E,	Strut	9 × 8
F,F,	Auxiliary rafters, at bottom	10 × 8½
H,H,	Principal rafters, at bottom	10 × 8½
I,	Studs supporting the principals	8 × 8

This roof is much better constructed than the original one by Inigo Jones. A truss of the present design contains only 98 cubic feet of timber, whereas that by Inigo Jones had 273, and was very insufficient at the joggles, and had some of its timbers very ill disposed: the interior truss is well contrived for supporting the exterior, which reaches seven feet beyond the walls. The tie-beam has, perhaps, too much camber, being six inches; for since it acts as a string, it will lengthen in the settling of the roof.

Figure 3 represents the roof of Drury-lane theatre, 80 feet 3 inches span, and the trusses 15 feet apart; constructed by Mr. Edward Gray Saunders. This was destroyed by fire in 1809.

This is rather a curious form of roof; the principal truss is simply one of the second class with queen-posts and straining-beam, but above this, and partially resting upon it, are three other smaller trusses, which form the outer-roof. These are simple trusses of the first class with king-post and struts, the central one having a continuous bearing on the straining-beam of the main truss, and the side ones resting at one end on the straining-beam, and at the other on the wall.

		Inches Scantling.
A,	Beams	10 × 7
B,B,	Rafters	7 × 7
C,	King-posts	12 × 7
D,	Strut	5 × 7
E,	Purlins	9 × 5
G,	Pole-plates	5 × 5
H,	Common-rafters	5 × 4
I,	Tie-beam	15 × 12
K,	Posts to ditto	15 × 12
L,	Principal braces to ditto	14 and 12 × 12
M,	Strut	8 × 12
N,	Straining-beam	12 × 12

The principal beams are trussed in the middle space with oak braces, five inches square. This was requisite on account of its width, which is 32 feet, that the floors might carry the work-shops necessary for the use of the theatre. This truss, which is most admirably constructed, is hardly to be equalled for strength, stiffness, and lightness, and will safely bear a load of nearly 300 tons, which is four times more than ever it is likely to be loaded with.

Plate VII. *Figure* 1, exhibits the roof of Covent Garden theatre. The tie-beam in this case is supported by five suspenders, a king-post in the centre, and two queen-posts on either side; between the two innermost queen-posts is a straining-beam, and on the other sides of them are auxiliary-rafters, which abut against a shoulder near their heads. A strut is carried from the foot of the inner queen-post to the head of the outer. The straining-beam is suspended by two queen-posts, between which is another straining-piece, and a strut from their head to the angle formed by the king-post and straining-beam below. The posts are all made double, and are shown in the Plate above the roof in their respective places.

Figure 2 represents the present roof of Drury-lane theatre. There are here both principal and auxiliary rafters, the tie-beam being suspended at two points from the former, and at two from the latter, the two first queen-posts being the inner ones. These are kept apart by a straining-beam, against which they are pressed from the other side by the auxiliary rafters; struts are placed between the feet of the principal and the head of the secondary queen-posts, and the bearing of the sub-rafters is still further reduced by a strut from the foot, and on the other side of the smaller queen-posts. The straining-beam is supported by a king-post from the apex of the principals, which in their turn are supported by struts from the foot of the king-post, the other portion having a continuous bearing on the auxiliary rafters.

The Figure above on the left-hand, shows how the timbers join at the top of the queen-posts, and that on the right how the timbers join at the end of the tie-beam.

The roof over the church of St. Martin-in-the-fields, designed by Gibbs, is rather curious. The entire breadth of the building is 69 feet, which is divided into 3 parts, the nave measuring 40 feet, and the remaining 29 feet being divided between the two aisles. The central portion is covered by

a truss, which is supported at either end by an upright timber-post above the columns, and at two intermediate points by braces from these posts to the tie-beam, which is suspended from the principals at three points by a king-post and two queen-posts; struts are carried from the foot of the king-post to the head of the queen-posts, and from the feet of the latter to the principals. Above the aisles, hammer-beams are supported at one end on upright posts in the wall; and at the other, on the post above the columns, and two intermediate bearings are afforded by struts from the same posts. The main principals have a continuous bearing on the rafters of the truss over the roof, another on a post which rests upon the hammer-beams, and at the extremities are strapped to the hammer-beams. From the last-named post there is a brace to the top of post over column. The scantlings of the timber are rather full, and are as follow :—

Main principal, 13 inches by 10 inches at bottom, and 11 inches by 10 inches at top.

Straining-brace or principal of nave-truss, 14 inches by 10 inches at bottom, and 11 inches by 10 inches at top.

King-post, 9 inches by 9 inches.

Strut on king-post, 7 inches by 7½ inches.

Queen-post, 8 inches by 9½ inches.

Strut on queen-post, 7 inches by 7½ inches.

Tie-beam, 14 inches by 9½ inches.

Post over column, 14 inches by 9½ inches.

Brace below tie-beam, 7 inches by 7 inches.

Hammer-beam, 14 inches by 9½ inches.

Brace from uprights to hammer-beam, 8 inches by 8 inches.

Post on hammer-beam, 8 inches by 9 inches.

Purlin rafters, 4 inches by 6 inches.

The roof the basilica of St. Paolo fuori le murà, executed in the fifteenth century, has double trusses, each consisting of two similar frames nearly 15 inches apart, and placed at intervals of 10½ feet from each other. The tie-beam, which is in two lengths scarfed together and secured by three iron straps, is suspended at three points by a king and two queen-posts, the latter being separated by a straining-beam, and having auxiliary rafters abutting against their heads. The king-post is of curious construction, and consists of three pieces for the double truss; that piece against which the principals abut, is very short, only extending as low as the straining-beam. Between the trusses another piece is placed, and sustained by a strong key of wood passing through it and the two upper short pieces; and this piece, in its turn, sustains the tie-beams by means of another strong key. The scantlings are :—

Tie-beams, 22½ inches by 15 inches.

Principal rafters, 21¾ inches by 15 inches.

Auxiliary rafters, 13¾ inches by 13¼ inches.

Straining-beam, 15 inches by 12¾ inches.

Purlins, 8½ inches by 8½ inches.

Common rafters 5¼ inches by 4¼ inches.

The purlins are 5 feet 7 inches apart, and the rafters 8½ inches.

The span of the roof is 78 feet.

The roof over the Passengers' Shed of the Croydon Railway, at London Bridge, is of simple construction, consisting only of tie-beam, principals, and iron suspending-rods, with timber-struts between each two, the tie being suspended at eleven points.

The tie-beams, principals, and struts being framed together, the suspending-rods are introduced, and screwed up by nuts upon their lower ends, until the whole is firmly united. The tie-beams camber 6 inches in the centre. There are 14 of these trusses, 12 feet 6 inches apart, connected by the ridge-piece and purlins. These extend to within 25 feet of either end, where a half-truss of similar construction is framed into the centre of each extreme truss at right angles to the same, to form the hip, with ridge-pieces as usual. The whole is covered in with 1¼-inch rough boarding, upon which zinc is laid and joined. The under side of the roll that covers the joint is grooved to admit the edges of the zinc, and the angle next it rounded, to allow the zinc to expand or contract. The rolls are painted, and are sometimes covered with zinc or lead.

The entire length of the Passengers' Shed (to which this roof belongs) is 212 feet, and 53 feet wide. There is room for about 24 carriages, which is divided into three lines of rails; the outer lines being for the arrival and departure of trains, and the centre line for spare carriages. On each side of the shed is a platform raised nearly level with the floor of the carriages, 11 feet wide, and connected at the end; this is covered with asphalte, and coped next the rails with stone. In the centre of the shed is a carriage-truck, that moves transversely to the rails, for the purpose of shifting carriages from one line to another, when any extra are required in a train. Between the rails of each line (170 feet in length) the ground is sunk between walls a sufficient depth to enable workmen to get at the under side of the carriages and engines when required.

The roof of Christ's Hospital is well worthy consideration. It covers an area 51 feet wide by 187 feet in length, and consists of principal trusses running across the building, with smaller longitudinal trusses between every two main trusses, to carry the rafters. In the main truss the tie-beam is suspended from five points by king and queen-posts, which are however of iron, and bolted through the tie. Between the two innermost queen-posts, or suspenders, is a straining-beam, which abuts against their heads and is also bolted to the principals; its length is 16 feet, and it is supported at two intermediate points by struts from the feet of the queen-posts; there is also another strut for the other side of the post to the head of the further or outermost one. The extremities of the tie-beams and rafters rest in iron shoes, and partially upon cast-iron standards supported on stone corbels 10 feet below the ceiling line.

The five longitudinal trusses, to support the main rafter between the principal trusses, is extended from each queen post in one cross truss to the corresponding one in the next; the distance between the main trusses, and therefore the length of the tie-beams, being 17 feet. These are simple king-post trusses without struts, and carry the main rafter on top of the king-post, which, in this case, is of timber, bolted to the tie-beam. Filling-in beams are placed between these trusses to receive the ceiling-joists. The scantlings of this roof are as follow :—

Principal truss :

Tie-beam, 14 inches by 14 inches.

Principal rafters outside the innermost queen-posts, 12 inches by 9 inches at lower end; 10 inches by 9 inches at upper end.

Principals within and above the innermost queen-posts, 9 inches by 9 inches.

Straining-beam, 12 inches by 9 inches.

Struts, 6 inches by 6 inches, (longitudinal trusses.)

Tie-beams, 12 inches by 7 inches.

King-post, 6 inches by 6 inches.

Struts, 6 inches by 6 inches.

Main rafters between trusses :—

At lower ends, 12 inches by 7 inches.

At upper end, above queen-posts, 9 inches by 7 inches.

Common rafters, (longitudinal) 7 inches by 5 inches.

The roof over Exeter Hall is of simple construction, the

span being not less than 76 feet, and the height of the roof from the underside of the tie-beam, 21 feet 6 inches; the trusses are placed at alternate intervals of 2 feet 6 inches, and 9 feet.

Each truss has the tie-beam, which is scarfed, suspended in six points by queen-posts, the innermost pair being provided with a straining-beam, and with auxiliary rafters on the other side of them, each of which is supported by two struts resting on the foot of the queen-posts. The two outermost queen-posts on either side are hollow, and are suspended from the principal rafters, as are also the inner ones, by means of straps. The straining-beam, which is 22 feet long, is suspended from the apex of the principals by a king-post, from which struts are raised to shorten the bearing of the principals. Two sloping timbers but against the feet of the inner queen-posts, from the apex of which an iron suspender is bolted to the tie-beam. The ends of the tie-beams and principals rest in iron shoes. The scantlings are:—

Tie-beams, 14½ inches by 7½ inches.
Principals, 8½ inches by 7½ inches.
Auxiliary rafters, or under principals, 14 inches by 7½ inches.
Inner queen-posts, 8½ inches by 7½ inches.
Outer ditto, 10 inches by 4½ inches.
Intermediate ditto, 12 inches by 4½ inches.
King-post, 6 inches by 7½ inches.
Straining-beam, 14 inches by 7½ inches.
Braces, 7½ inches by 7½ inches.
Upper ditto, 6 inches by 7½ inches.
Purlins, 7½ inches by 4 inches.
Common rafters, 5 inches by 2½ inches.
Ridge-piece, 8 inches by 3½ inches.
Wall-plates, 13½ inches by 6½ inches.
Pole-plates, 12 inches by 4 inches.

The truss over the arched roof of St. George's Hall, Liverpool, which is 65 feet in width, is of very simple construction. The tie-beam is sustained at five points by a king-post and four queen-posts. The principals have auxiliaries under them, but do not meet at an apex, reaching only as far as the inner queen-posts, which are kept apart by a double straining-beam at top, and by another at their feet. Struts are placed between the head of the king-post, and feet of the queen-posts, and thence again to the head of the outer queen-posts.

Having given these descriptions of various kinds of roofs, it will not be out of place to give some rules for finding the proper scantlings of the different members, as determined by Tredgold, and the manner in which each member is affected.

King-Post.—The king-post is intended to support the ceiling, and by means of the braces, to support part of the weight of the roof. The weight suspended by the king-post, will be proportional to the span of the roof; therefore, to find the scantling:

Rule.—Multiply the length of the post in feet, by the span in feet. Then multiply this product by the decimal 0.12 for fir, or by 0.13 for oak, which will give the area of section of the king-post in inches; and this area divided by the breadth, will give the thickness; or by the thickness, will give the breadth.

Queen-Posts.—Queen-posts and suspending-pieces are strained in a similar manner to king-posts, but the load upon them is only proportional to that part of the length of the tie-beam suspended by each suspending piece or queen-post. In queen-posts, the part suspended by each is generally half the span.

Rule.—Multiply the length in feet, of the queen-post or suspending piece, by that part of the length of tie-beam it supports, also in feet. This product multiplied by the decimal 0.27 for fir, or by 0.32 for oak, will give the area of the section of the first in inches; and this area divided by the thickness will give the breadth.

Tie-Beams.—A tie-beam is affected by two strains, the one in the direction of the length from the thrust of the principal rafters, the other is a cross strain from the weight of the ceiling. In estimating the strength, the thrust of the rafters need not be considered, because the beam is always abundantly strong to resist this strain; and when a beam is strained in the direction of the length, it rather increases the strength to resist a cross strain. Therefore the pressure of the weight supported by the tie-beams will be proportional to the length of the longest part of it that is unsupported.

To find the scantling of a tie-beam, which has only to support a ceiling, the length of the longest unsupported part being given:

Rule.—Divide the length of the longest unsupported part by the cube-root of the breadth; and the quotient multiplied by 1.47, will be the depth required for fir, in inches; or multiply by 1.52, which will give the depth for oak in inches.

Principal Rafters.—In estimating the strength of principal rafters, we may suppose them supported by struts, either at or very near all the points where the purlins rest upon. The pressure on a principal rafter, is in the direction of its length, and is in proportion to the magnitude of the roof; but the effect of this pressure does not bear the same proportion to the weight, when there is a king-post, as when there are queen-posts; therefore the same constant number will not answer for both cases.

Case 1.—To find the scantling of the principal rafter, when there is a king-post in the middle.

Rule.—Multiply the square of the length of the rafter in feet, by the span in feet, and divide the product by the cube of the thickness in inches. For fir, multiply the quotient by 0.96, which will give the depth in inches.

Case 2.—To find the scantling of a principal rafter, when there are two queen-posts:

Rule.—Multiply the square of the length of the rafter in feet, by the span in feet, and divide the product by the cube of the thickness in inches. For fir, multiply the quotient by 0.155, which will give the depth in inches.

Straining Beams.—A straining-beam is a horizontal piece between the heads of the queen-posts. In order that this beam may be the strongest possible, its depth should be to its thickness as 10 is to 7.

Rule.—Multiply the square root of the span in feet, by the length of the straining-beam in feet, and extract the square root of the product. Multiply the root by 0.9, for fir, which will give the depth in inches.

To find the thickness, multiply the depth by the decimal 0.7.

Struts and Braces.—That part of a roof that is supported by a strut or brace, is easily ascertained from the design; but the effect of a load must depend on the position of a brace; when it is square from the back of the rafter, the strain upon it will be the least; and when it has the same inclination on the roof, the same strain will be thrown on the lower part of the principal rafter, as is borne by the strut. But as the degree of obliqueness does not vary much, we shall not attempt to include its effect in the rule for the scantling.

Rule.—Multiply the square root of the length supported in feet, by the length of the brace or strut in feet, and the square root of the product multiplied by 0.8 for fir, will give the depth in inches, and the depth multiplied by 0.6, will give the breadth in inches.

Purlins.—The stress upon purlins is proportionable to the distance they are apart, and the weight being uniformly diffused, the stiffness is reciprocally as the cube of the length.

Rule.—Multiply the cube of the length of the purlin in feet, by the distance the purlins are apart in feet; and the fourth root of the product for fir will give the depth in inches; or multiplied by 1.04, will give the depth for oak; and the depth multiplied by the decimal 0.6, will give the breadth.

Common Rafters.—Common rafters are uniformly loaded, and the breadth need not be more than from 2 inches to 2¼ inches. The depth for Welsh slate may be found by the following rule:

Rule.—Divide the length of bearing in feet, by the cube root of the breadth in inches; and the quotient multiplied by 0.72 for fir, or 0.74 for oak, will give the depth in inches.

The largest roof ever executed was that of the Riding House, built at Moscow, in 1790, by Paul I. Emperor of Russia. The span was 235 feet, and the slope of the roof about 19 degrees. The principal support of this immense truss consisted in an arch or curved rib of timber, in three thicknesses, indented or notched together, and strapped and bolted with iron. The principal rafters and the tie-beams, were supported by several vertical pieces notched to the curved rib; and the whole stiffened by diagonal braces. The disposition of the parts of this roof is extremely ingenious; but it was too slight for the immense extent of the span, and it appears that it settled so much, that it was proposed to add another curved rib to the original design. This example affords an instance of the impropriety of adding material so near to the neutral line of the framing; a like want of attention to principle is sometimes found in a first design; a roof designed by Bettancourt for a riding-school, as given by Kraffit, is an example. The external dimensions of the building were 1,920 feet by 310 feet; it was lighted from the top by a lantern; and there was a gallery round the inside of the building for spectators. The method of notching the timber in the curved rib, is objectionable, on account of the danger of the splitting of the timber under a considerable strain. This system of trussing is termed the *bow suspension truss*, and has been much used of late for bridges for railway-works.

Of a somewhat similar construction are the roofs executed by Philibert de Lorme, in the sixteenth century, which are constructed with a series of arched timber ribs in lieu of trusses, these ribs being formed of planks in short lengths, placed edgewise, and bolted together in thicknesses, the planks in one thickness breaking joint with those in the adjoining thickness.

A fine example of this class of roof was that constructed over the Halle au Blé, at Paris, 120 feet in diameter, which has been destroyed by fire.

A smaller example, but nearer home, is to be found over the central compartment of the Pantheon, Oxford-street; the span measures 38 feet. The roof is circular, and is supported by nine semicircular ribs. Each rib is in three thicknesses; the middle thickness is of teak, the side thicknesses or flitches are of fir; the pieces of timber forming these thicknesses are scribed on the under side to the curve of the roof, (and ceiling,) but the top edge is left straight; therefore at their abutting ends they are considerably broader than at their middle. Each abutment of every piece, throughout every rib, has a shoe of cast-iron interposed. Iron bolts connect the three thicknesses together at each end, with a washer connecting each pair of bolts, as explained on the section. The ribs rest alternately on the pillars, (hereafter described) and on the centre of the longitudinal plate extending the whole length of the roof. In the former case the ribs are framed into strong upright pieces, which become the king-post of a semi-truss. These semi-trusses, besides carrying the timber of the roof and ceiling over the galleries, are calculated to receive the lateral thrust of the semicircular roof, a large cast iron shoe laid upon a stone template, receives the end of the tie-beam of these semi-trusses next the outer wall; the object of this shoe being to prevent the possible decay of this end of the beam from affecting the stability of the roof.

There is also a cast-iron shoe receiving the other end of this beam, which is formed with sockets and flanges, so as to receive and connect together the king-post and tie-beam of the above named semi-truss, and the longitudinal plate alluded to above, and the head of the great iron upright or pillar. The chief use of this iron shoe is to prevent the lateral compression of the timbers, and to prevent the natural shrinkage of the horizontal plate from letting down the roof.

The intermediate ribs (those which do not rest on the iron pillars) rest on another iron shoe, which is fitted on to the head of an upright piece that rests on the centre of the longitudinal plate; but the bearing is thrown on to the iron pillars by stout braces framed into the said upright piece and longitudinal plate.

It will thus be seen, that throughout the skeleton of this roof there is no case of any important timber resting with its *end* upon the *side* of any other piece, but that they all bear with an *end-grain* abutment, so that the cracks and failures arising from the necessary shrinkage, as well as from the lateral compression of the timbers, are avoided. This was a precaution rendered necessary by the very large scantlings of the timbers, and by the discharge of the whole weight of roof and ceiling being thrown on so few points of support. The circular part of the roof is covered with copper laid on diagonal boarding, which is supported on rafters notched on to the great ribs, and running longitudinally. The roofs over the sides or galleries are slated, with a flat plaster ceiling; the ceiling of the circular part is deeply panelled, the main ribs forming the core for the cradling. The enrichments are of papier maché, a material that was well adapted for the large architectural ornaments, from its lightness, and from the safety with which it could be screwed up to the timbers.

The longitudinal plate above alluded to consists of two pieces of fir, each 12 × 6, bolted together: the bearings between the iron pillars are reduced by braces, which discharge the bearing on to the iron pillar, and at the same time receive the wood cradling for the spandrels. Each end of this plate is let into the wall, and is received by a corbel of teak wood, on to which it is bolted and locked down.

A considerable improvement upon the system of Philibert de Lorme was effected by Colonel Emy, a French engineer, in the early part of the present century, by the employment of *laminated* ribs. The principal difference between the two consists in this, that in Colonel Emy's improvement the direction of the fibres of the wood coincides with the curvature of the rib, and in consequence the joints are much less frequent, and the rib possesses greater elasticity, so as slightly to yield, rather than break, under any violent strain. The alternate thicknesses break joint, as in De Lorme's roof, and all are securely bolted together.

The earliest roof constructed after this fashion was at Marac, near Bayonne, in 1825. The span is 65 feet, and the main ribs are formed of planks bent round on templates to the proper curve, and kept together by iron straps, and also by the radiating struts which support the principals; they are in pairs, notched out so as to clip the rib between

them. In this roof the entire weight of the roof is thrown on the walls at the feet of the ribs, which are considerably below the principals, so that the weight of the upper part of the walls serves to diminish the effect of any thrust against the lower part of the walls. A great saving of wall-material is hereby effected.

This principle has often been applied in the case of railway bridges, and there is at present one erecting at the London terminus of the Great Northern Railway. In this instance the spandrels are of cast-iron.

Of somewhat similar construction is the roof over the transept of the Great Exhibition building. The principals, or main ribs, of which are placed at intervals of 24 feet from centre to centre, and are made up of three planks, two of 2 inches in thickness, and the middle one 4 inches thick, with a moulded piece on the under side $2\frac{3}{8}$ inches thick, and two 11-inch planks at the top, each one inch thick, and nailed together to form the gutter-board, the whole being firmly connected together by wrought-iron bolts passing through belts of the same material, running at top and bottom of each rib. In order to form the ribs with the proper curvature, each plank, $13\frac{5}{8}$ inches wide, was cut on one edge to its proper segmental form, and the two complements cut off were nailed to the lower or straight edge of the flank ; the whole being put together, so as to breach joint throughout, the length of each section so cut being about 9 feet 4 inches. The preparation for the reception of the ends of the purlins was on this wise: the two wide planks were cut across, so as to form a cavity to admit the ends of the purlins, the parts of the planks thus separated being connected together by cast-iron plates. The openings thus made were filled in temporarily with wooden blocks, until the joiners were ready to fit in the ends of the purlins.

The strength of every purlin has been duly calculated, according to its relative position in the arch ; thus, the three uppermost purlins, having the greatest strain on them, are each $13\frac{1}{2}$ inches in depth by $4\frac{1}{2}$ in width ; while the four lower purlins on each side, having gradually less strain to bear, diminish regularly in depth to 9 inches, all having the same width as those at the crown ; whereas, the lowest one on each side of the arch, being nearly horizontal, is increased to a scantling of 8 inches by $6\frac{1}{4}$ inches.

Between each pair of main ribs are two intermediate ribs, or, as called in ordinary roofing, common rafters, 4 inches deep by 3 inches wide. On the top of these are gutter-boards, in two thicknesses, as those described for the main ribs. The gutters, each 5 inches wide, are formed by two splayed fillets, let into and nailed securely to the upper side of the boards. These fillets also serve as abutments for the skylight bars, which are rather larger in section and size, as those for the skylights in other parts of the building. Each bar is nailed at the lower end to the fillet, and at the upper end to the ridge-piece, which is formed of three pieces of fir, one above another, the lower section being 4 inches wide by $1\frac{1}{4}$ thick ; the middle piece, 3 inches by $\frac{13}{16}$ths inch ; and the upper piece, 2 inches by $1\frac{3}{8}$ths inch, the latter having a groove on each side to receive the glass. The three thicknesses are necessary, in order to suit the curvature of the arch. The lower end of each ridge-piece is carried down to, and rests on, the lead flat. Condensation-gutters are formed in this roof, as in the roofs of the aisles and avenues, but by a different method. A sloping fillet is nailed on to each side of the gutter-board, and continued from the springing of the arch on one side, to the corresponding point on the other. With a view to retain the ridges in their places, wrought-iron rods of $\frac{3}{8}$ inch diameter, extend from the purlins to the under side of the ridges. In order thoroughly to carry off the rain-water from every part of the roof, all the skylight bars are fixed diagonally from the ridge to the gutter, and the water collected in each curved gutter, is carried into a sloping trough at bottom, and thus discharged on to the lead flat, which is sloped towards the water-heads at tops of the hollow columns. Looking at the roof from the lead flats, the whole has a herring-bone appearance.

Temporary ladders, fixed to suit the arched roof, were used for fixing the ridge-pieces, skylight bars, &c. ; but, in order to facilitate and expedite the glazing of this roof, travelling scaffolds were used, which could be raised and lowered at pleasure, by means of ropes and pulleys, and by the power of four men working a crab engine, placed on the lead flat contiguous. Each travelling scaffold is formed with sides and ends, and has boxes, in convenient positions, for the glass, putty, and tools ; the whole running on small friction rollers, suited to the tops of the ridge-pieces, which serve as rails : without such a contrivance, the glazing of the roof of the transept would have been almost an endless job.

The vertical supports for the roof consist of cast-iron columns placed one above another in three tiers, sixteen in each tier on either side. Above the top pier are fixed the trussed girders, 3 feet in depth, spanning from column to column, which are each 24 feet from centre to centre ; and across the intersecting lines of the middle arch, are two double trussed girders, 6 feet in depth, and corresponding in length with three spaces of 24 feet each ; except under the columns of the south-east angle of the transept, the whole are placed on broad base plates, which rest on concrete foundations. In the exceptional case, the foundation consists of a solid brick pier, built in cement. At the top of each column which supports the roof, is a cast-iron socket, 4 feet 4 inches in height. The use of these sockets is to receive what may be termed the vertical legs or supports of the ribs, and which form parts of the ribs as framed together on the ground. In order to resist the lateral thrust of the roof, a strong gangway, 24 feet wide, is formed on each side of the transept, which may be considered as an abutment, being constructed of strongly-framed and braced flooring, supported by trussed girders. The main ribs have their bearing immediately above the columns, the intermediate ones on the girders between the columns.

The following is a description of a system of construction in roofs, invented by M. Laver, architect to the king of Hanover. It is also applicable to bridges, and similar works.

This new principle consists in a combination of the two principal forces of materials—that of resistance to compression and resistance to tension. The first of these forces has been used from the remotest periods in the construction of bridges, and arches in general ; the second has been more lately employed—at least in Europe—for the construction of suspension bridges by the application of chains. The first requires great masses of materials and strong abutments ; the second requires less materials than the first, but secure fastenings, for the chains are frequently obtained with difficulty. Very sensible vibrations and undulations are experienced where this last mode of construction is employed.

The disposition of the principal parts of this truss is, that of two segments of a circle, placed with the concave sides opposite each other, and tied together at the extremities, being further connected together, or rather kept apart, from each other, by vertical and diagonal struts. Imagine two bows so disposed ; it will be perceived, the chain a k g, fastened at the extremities of the upper bow, acts with the positive force of tension, which the strongest materials possess, varying from 10 to 20,000 lbs. for every square inch of the transverse section of the several kinds of wood employed

in construction, and from 20 to 100,000 lbs. for the several metals.

The bow, a d g, by its resistance to compression, serves to prevent the chain, a k g, from contracting or drawing together the extremities a and g. The lower bow a k g, acting as a chain, prevents the upper bow, a d g, from pushing or pressing out at the points of support. The vertical and diagonal struts unite in a firm manner the two bows, and the two forces thus neutralized form a complete whole, that sustains itself, and can neither thrust out nor draw in.

It must be observed, first, that the strength of the chains, which act in a similar manner to that of suspension bridges, depends upon the depth of the versed sine, and that the more they deflect below the horizontal line, or chord of the arc, the stronger they would be; secondly, that the upper bow, owing to the elasticity of the material, must absolutely have the convex form; so that, when any great sudden weight is thrown on it, causing the lengthening of the chains by tension, and the shortening of the upper bow by compression, the upper bow may not be reduced to a horizontal line, a n g, beneath which it could no longer serve by resistance to the statical equilibrium of the construction; thirdly, that the method of combining the extremities, a and g, of the bows, must depend upon the materials employed: for instance, in a wooden bridge, the notching and scarfing at the joints of the different pieces of wood ought to be calculated and executed to the force which they have the power of resisting. The rules and forms most applicable to these joints have also been proved by the experiments of the inventor.

This system of construction is applicable to roofs and bridges of every denomination, such as draw and swing bridges, but especially for suspension bridges, where the locality on either side, or on both, does not admit of secure fastenings for the chains. For covering large rooms, riding-schools, and other openings of large space, it is particularly useful; also the erection of scaffolding, and ladders of large dimensions, and to the stiffening of beams, masts, and supports in general.

The application of this system to roofs and floors of large span, is extremely economical and useful, and by simple modifications serves for the covering of large spaces, without any intermediate points of support, and also presents this farther advantage, that from its vertical pressure, it requires no other support than walls of moderate thickness. When applied to floors, bridging-joists will remedy the inequality of the surface in the beam itself. In roofs of larger span, the posts may be continued upwards, so as to receive the purlins, and when continued downwards, serve to hold up the ceiling, whether flat, vaulted, or mixed.

The open Gothic roofs of the middle ages, differing as they do in essential matters of construction from those at present in use, ought not to be passed over in silence. In many, if not the majority of such roofs, tie-beams were altogether dispensed with; the only tie between the principals, to prevent their spreading, consisting of a collar-beam placed high up in the roof. So much care, however, to prevent spreading, in these roofs, was not required; for the principals were laid at a high pitch, and therefore had not so much tendency to thrust outwards, as a roof of modern construction; beside which, the walls were built of very great thicknesses, and were often strengthened by massive buttresses. Sometimes, in lieu of a collar-beam, two cross-braces were used springing at about half way up the principals, and intersecting each other in their course upward to the opposite principal, and occasionally these and the collar-beam were employed in the same roof; not unfrequently we find the collar strutted up from the rafters. Sometimes again, the principals rest on arched beams or planks, of which some are carried down the walls, and rest on corbels projecting from them; by this means, the thrust is carried down lower, and you gain the advantage of the weight of the walls above, to resist it.

Sometimes tie-beams are used, which are usually of large scantling, and have the upper surface sloped upwards to the centre, so that the depth there is greater than at any other part. Occasionally, upon the centre of the tie-beam is placed a post, from which spring branches to prop up the collar beam, and sometimes the rafters also. This post must not be confounded with the king-post of modern roofs, for it is not used to hang up the tie-beams, but rests upon the tie-beams to support the upper part of the roof.

Such were the most usual form of roofs in the earlier Gothic examples; but at a later time, when the pitch of the roof was lowered, other methods were adopted. Sometimes, merely a horizontal beam was thrown across the upper side, being formed into two inclined planes similar to the tie-beams mentioned above; at others, inclined rafters were used with their ends resting upon upright posts, placed against the walls and resting on projecting corbels at a distance from the top of the walls, the rafters being connected with it by a curved strut, so as to prevent deflection of the rafters near the centre. The upright posts are termed pendant posts, and the struts are often cut out of thick planking, so forming solid spandrels.

Frequently a horizontal beam is laid across the roof on top of the pendant posts, supported by curved struts as before, and above this, rafters are introduced, strutted up in the centre from the horizontal beam. Where the pitch is somewhat higher than usual, inclined struts are added to the central strut, so as to divide the bearings of the rafters. This kind of roof is very similar in appearance to a king-post truss, but this is not the case; that which has the appearance of the king-post, not being employed to suspend the tie-beam, but to support the rafters.

The hammer-beam roofs so common in halls of the 15th and 16th centuries, are of a different description to any of the above. They are usually of a high pitch, and of considerable span, and often bear evidence of very great skill in construction: a simple roof of the kind, consists of two principals connected by a collar-beam, and resting on the ends of two hammer-beams, which project horizontally from the wall and carry two queen-posts. The queen-posts and the collar-beam are usually connected by a curved brace, as are also sometimes the hammer-beams with pendant posts. Of such roofs, the most remarkable are those of Hampton Court and Westminster Hall.

The roof of the great hall, Hampton Court, consists of principals which fall short of the apex, and are secured to a collar or straining-beam at their upper extremities, which is supported by three vertical posts resting on a lower collar-beam, at about halfway down the principals. Under the lower end of the principals, and resting on the top of the walls, is a hammer-beam projecting out about a quarter of the entire space, and supported at its inner extremity by a curved brace, which rests upon a pendant post, and this again upon a corbel projecting from the wall. The hammer-beam carries two uprights, one of which supports the principal rafters, and the other the lower collar, which is still further supported at its centre by a curved brace, which rests upon the extremity of the hammer-beam. A couple of inclined rafters springing from the top of the principals, meet at an apex over the centre of the roof, where they are supported by a strut resting on the collar-beam.

The roof of Westminster Hall has always been much admired; and to its great height and extensive dimensions,

must be attributed much of the grandeur of the building. It is, indeed, impossible to enter this magnificent room, without being struck with admiration. An uninterrupted open space, nearly equal to the size of a large cathedral church, is presented in one view, and the scientific spectator, gazing with delight on its lofty roof, admires the elaborate and artist-like arrangement of its timbers. These serving at once the purposes of utility and decoration, and uniting the apparently opposite qualities of massive solidity and airy lightness.

The angle of the roof is formed on what country workmen still term common pitch, the length of the rafters being about three-fourths of the entire span. The cutting off the girders, or tie-beams, which, crossing from wall to wall in common roofs, restrain all lateral expansion, was the first circumstance peculiar to this construction. To provide against lateral pressure, we find trusses, or principals, as they are technically designated, raised at the distances of about eighteen feet throughout the whole length of the building. These trusses abut against the solid parts of the walls between the windows, which are strengthened in those parts by arch-butresses on the outside. Every truss comprehends one large arch, springing from corbels of stone, which project from the walls at twenty-one feet below the base-line of the roof, and at nearly the same height from the floor. The ribs forming this arch, are framed at its crown into a collar-beam, which connects the rafters in the middle of their length. A smaller arch is turned within this large one, springing from the hammer-beam which is level with the base-line of the roof, and supported by two brackets or half-arches, issuing from the springers of the main arch. By this construction of the trusses, each one acts like an arch, and by placing these springers so far below the top of the walls, a more firm abutment is obtained. The main arched rib is constructed of three thicknesses, somewhat after the principle of Philibert de Lorne. From the extremity of the hammer-beam rises a vertical post which supports the end of the collar-beam already alluded to, and this again, by means of two other cubical posts, supports a second collar-beam, and a central or king-post.

Of late years, many roofs have been constructed of iron, a material which at first began to be introduced for particular members, such as tie and suspension-rods, but afterwards became employed for the entire truss, and sometimes for the covering likewise. Iron roofs are for the most part of similar construction to those already described of timber, those members which are subjected to tension, such as ties and suspending rods, being of wrought-iron rods, and those which suffer compression, such as principals and struts, of cast-iron. Such roofs have been very extensively employed in railway works, for the covering of passenger and engine sheds, and such like.

The roof of the passengers' arrival and departure shed at Euston Grove has a very light and elegant appearance; it is constructed principally of wrought-iron, the bressumers, columns, and gutters, only being of cast-iron. The entire width is 80 feet, formed in two spans of 40 feet each, a row of iron columns and bressumers supporting the rafters in the centre and outside, and on the opposite side by iron corbels built in the wall, and further secured thereto by strong bolts and nuts; the rafters are six feet eight inches apart, and are of wrought iron, in form of the letter T; the slate battons, as they may be called, are of angle-iron, firmly riveted to the back of the rafters, at such a distance as the slates require, and to which they are secured by strips of copper. The roof is firmly tied from side to side by a tension-rod of one inch and a quarter diameter, to each pair of rafters, and is further supported and braced by struts of T iron and suspension-rods, with nuts and screws to adjust their length. The entire length of the roof is 200 feet; the gutters are cast in lengths of 10 feet each, joined together by flanges and bolts, and so fixed as to form an incline towards each column, which, being cast hollow, and having a pipe connected with a drain, they form a convenient and easy conveyance for rain from the roof.

The truss consists of two principals—a tie-beam, which is sustained by three suspending-rods and four struts, two on either side; one from the head of the central suspending-rod to the foot of the outer one, and another thence to the principal.

The roof of the locomotive engine-house at Camden Town is of very similar construction to the one above described: the rafters are of T iron, and the slates are supported by angle-iron riveted to the rafters. There are cast-iron chairs secured down to a stone coping on the walls, and from which the rafters spring; each pair of rafters is tied by means of a tension-rod, and otherwise supported and braced by struts of T iron, and suspension-rods of round iron, which make the whole very firm, and gives it a light and pleasing appearance.

Both these roofs were manufactured and erected by Messrs. Cubit, of Gray's Inn Road, under the direction of C. Fox, Esq., now resident engineer to the Company.

Of the numerous roofs of this material which have been erected over railway works, the following examples will give some of the principal varieties. The first, for a roof 30 feet span, consists of two principals, with tie-rod, which is suspended at two points, by two oblique rods meeting at the apex, by which means the king-rod is dispensed with. At the meeting of the suspension-rods with the tie-rod, a strut branches out at right angles to the principal, which it meets at half way. The rafters and rods are connected at the ridge in a separate casting, or the two ends of the rafters may be cast to half lap over each other, and the rods secured by wrought pins and nuts.

The rafters are of cast-iron of the ⌶ section, the dimensions of the lower table or flange being, in the centre of the length, 3½ inches wide, and at the two extremities, 1½ inch, with a thickness of ½ inch; and those of the upper table 2½ inches throughout the entire length, and ⅜ inch thick. The depth is the same throughout, being 4¾ inches.

The tension-rods are 1 inch round at the outer ends, and ¾ inch midway; and the oblique suspension-rods ¾ inch round throughout.

The second example for the same span consists of two principals and tie-rod, which is suspended at three points by a king-rod and two queen-rods, dividing the bearings into three equal parts: struts rise from the foot of the king-rod to the heads of the queen-rods.

The rafters are formed of two parallel bars, 3 inches by ¼ inch, having a wooden rib 1½ inch thick between them. The struts are of T iron, 2¼ inches wide over the top table, and ⅜ inch thick; rib 2½ inches deep, and ½ inch in thickness.

The tension rod is 1⅛ inch round, the king-rod ⅞ inch, and the queen-rods ⅝ inch round.

The timber between the bars in the rafters serves to fix battens for the covering,

The third example is for a roof 35 feet wide, constructed wholly of malleable iron. It consists of rafters and tie-rod, suspended at three points by king-rod and queen-rods, with struts from the bottom of the king-rod to the top of the queen-rods, and from the foot of the latter to the rafters.

The rafters and struts are of T iron, the rafters being 2½

inches, and the struts 2 inches, deep; the rib in both cases being $\frac{3}{8}$ inch, and the top table $\frac{1}{4}$ inch in thickness.

The tie rods are 1 inch round, the king-rod $\frac{3}{4}$ inch, and the queen-rod $\frac{1}{2}$ inch.

The fourth example is for a span of 60 feet, and consists of rafters and tie-rod, suspended at five points by a king and four queen-rods, two on either side. The four struts spring from the feet of the inner suspension-rod to the head of the outer.

The rafters are formed in the same manner as in the second example, of two parallel plates of bar-iron, with plank between; the scantlings are, however, somewhat heavier, the depth of the bar-iron being 4 inches, and its thickness $\frac{5}{16}$. The struts are of T iron, the top table being 3 inches wide and $\frac{1}{2}$ inch deep, and the rib $3\frac{1}{2}$ inches deep and $\frac{5}{8}$ thick.

The tension-rod is of round iron, and is, from the extremity to the first suspension-rod, $1\frac{1}{2}$ inch thick, thence to the second rod $1\frac{3}{8}$ inch, and thence to the king-rod $1\frac{1}{4}$ inch. The king-rod is $1\frac{1}{8}$ inch round, the intermediate $\frac{3}{4}$ inch, and the outermost $\frac{5}{8}$ inch. The fifth example is for the same span, and consists of rafters and tension-rod, suspended at five points by king-rod and four queen-rods, placed closer together than in the last example. There are six struts placed as above, but the last on either side buts against the rafter where there is no queen-rod.

The entire roof is of malleable iron, the rafters of the T-form measuring 3 inches across the top table, which is $\frac{3}{8}$ inch thick, and $3\frac{3}{4}$ inches in the depth of the rib, which is $\frac{1}{2}$ inch in thickness. The struts are also of T iron, the inner ones being $2\frac{3}{4}$ inches wide over the top table, which is $\frac{3}{8}$ inch thick, and $3\frac{1}{4}$ inches in the depth of the rib, which is $\frac{1}{2}$ inch thick. The outer struts are $2\frac{1}{2}$ inches wide over the top table, and $2\frac{1}{2}$ inches in the depth of the rib, the former being $\frac{3}{8}$ inch thick, and the latter $\frac{1}{2}$ inch.

The tension-rods are $1\frac{3}{8}$ inch round near the springing, $1\frac{1}{4}$ inch in the middle, and $1\frac{1}{8}$ near the king-rod.

In all such roofs, it is necessary to strengthen them with iron tie-rods, passing obliquely from the springing to the ridge across one bay, and secured on the under side of the purlins. The distance between the principals varies from 5 to 7 feet.

The roof over the Museum of Practical Geology, Piccadilly, of which Mr. Pennethorne was architect, is entirely of cast-iron, which is somewhat differently applied to any instance we have alluded to. The total width of the building is 67 feet, but there is an intermediate bearing on either side 6 feet from the external wall, thus making the clear width of the roof 55 feet. Each rib is composed of five separate pieces or girders, securely bolted together at the ends; the first piece, one end of which rests upon the wall, and the other on the intermediate bearing, is of a triangular form, with a perforated spandrel; the lower side is horizontal, resting upon the supports, the upper taking the slope of the roof, and the inner one springing from the inner support, with a curve of 5 feet radius, to range with the curvature of the other part of the roof, the radius of which is 48 feet. This girder is 1 foot 6 inches in depth, with a rib on either side in the centre. The next girder is of the same depth throughout, viz. 1 foot 6 inches, and in the cross section has a rib in the centre, and one of less projection at the lower edge; this portion is covered with slate slabs, $\frac{3}{4}$ inch thick. The central girder differs from the rest, being 2 feet in depth, with a flanche at top and bottom, the girder between being perforated for the sake of diminishing the weight; this portion is covered with glass. Each of the girders have abutment plates at the end, by means of which they are bolted together. The total rise or versed sine of the roof is about 12 feet.

The roof over the palm-house, Kew Gardens, is also worthy of description, on account of its exceedingly light and elegant appearance. The total length of this house is 362 feet 6 inches in the clear, the central portion measuring 137 feet 6 inches long, and 100 feet wide, by 63 feet high in the clear, exclusive of the lantern, which is 6 feet. The wings are each 112 feet 6 inches long, and 50 feet wide, and 27 feet high from the floor to the bottom of the lantern. The roof is in this case entirely of wrought-iron, the main ribs being formed of 9 inch deck-beam iron of circular section, hollow at the core, with four double flanges at right angles to each other. These ribs are obtained in lengths of about 12 feet, and are welded together to the required length, about 42 feet, and then bent upon a template to the requisite curvature.

The roof of the wings is of a single span, the rib being curved of a semicircular form, the extremities of which spring from the ground on either side of the plan, and foot into a solid block of granite, upon a concrete foundation. In the main or central building this semicircle is divided into two quadrants, which cover the aisles of this compartment, the lower ends being bedded upon granite, as above, and the upper ends into the tops of strong cast-iron columns which divide the width of this portion of the building into three aisles. From the top of the same columns springs a circular rib, similar to that in the wings, which is again surmounted by a lantern 6 feet in height. From the top of the columns brackets project, which on one side carry a gallery, running round the bottom of the upper roof, and on the other side serve to assist in the strengthening of the ribs. The column heads are connected by a continuous curb of similar scantling to the ribs, and the whole of the ribs are braced together and strutted by wrought-iron tie-rods, passing through cast-iron tubes, which act as purlins. These purlins are formed of a round bar $1\frac{1}{8}$ inch in thickness, welded in long lengths, and passing through the ribs, so as to form a continuous tension-rod all round the house at each purlin, with means of straining them as tight as possible. This tension-bar is covered or enclosed in a tubular bar of wrought-iron, exactly fitting between the ribs, and acting as distance-pieces in opposition to the strain of the tension-rods: thus is the entire structure compacted together. The distance between the main ribs is 12 feet 6 inches, and between the purlins 9 or 10 feet. This is in every respect a very elegant roof, and astonishingly light for so great a span.

The iron roof erected over the railway station at Lime-street Liverpool, is of great span, and of novel and ingenious construction. The area roofed over in one span extends from the façade in Lime-street to the viaduct over which Hotham-street passes, and from the inner faces of the receiving offices to about the middle of the old parcel offices on the opposite side; thus making the extreme length 374 feet and the breadth 153 feet 6 inches. The roof consists of a series of segmental principals, or girders, fixed at intervals of 21 feet 6 inches from centre to centre: these are supported on one side upon the walls of the offices, as far as they extend, and thence to the viaduct, a distance of 60 feet 4 inches, upon a box-beam of wrought-iron, whilst on the other side they rest on cast iron columns. The principals are trussed vertically by a series of radiating struts, which are made to act upon them by straining the tie-rods and diagonal braces; they are trussed laterally by purlins placed over the radiating struts, and intermediately between them, as well as by diagonal bracing, extending from the bottom of the radiating struts to the top of the corresponding struts in the adjoining principal. These diagonal braces are connected with linking plates, by a bar of the same scantling, and also

with the purlins already referred to. The curved ribs are thus firmly drawn together and attached to one another, and a rigid framework is formed, upon which the covering of corrugated iron and glass is laid.

Each principal girder is composed of a wrought-iron deck-beam, 9 inches in depth, with a plate 10 inches wide and $\frac{1}{4}$ inch thick, riveted on the top. The upper flange of the deck-beam is $4\frac{1}{2}$ inches wide and $\frac{1}{2}$ inch thick; the lower flange 3 inches wide and one thick: the web is about $\frac{5}{8}$ inch thick. This curved rib is formed of seven pieces connected with each other at the points where the radiating struts are attached, by means of plates riveted on both sides: these plates are 6 feet long, 7 inches broad, and $\frac{7}{16}$ inch thick. The beam is also strengthened at the haunches, for a distance of 27 feet from the springing, by plates 7 inches broad and $\frac{7}{8}$ inch thick, fastened by rivets.

There are 6 radiating struts in each rib, varying in length from 6 feet to 12 feet, the length increasing from the springing to the centre. They are similar in section to the principals, but are only 7 inches in depth, being attached to them, and to the tie-rods, by means of wrought-iron linking-plates. The top of the strut is made to touch the under side of the principal, in which position it is clasped by linking-plates, and secured by a bolt $1\frac{1}{4}$ inch in diameter.

The tie-rods in each rib are composed of three lines of rods between the two extreme radiating struts, and from these struts to the extremities of the principals they are in two lines, the sectional area in each case being the same, viz. $6\frac{1}{2}$ square inches. The ends of the tie-rods, which are prepared with eyes to receive the bolts, are placed side by side between the linking plates, attached to the struts, and a bolt is then passed through them: it will thus be evident, that if any elongation takes place in the ties, the struts will be acted upon.

The diagonal braces extend from the bottom of each strut to the top of one next towards the springing; they hold the struts tight up against the principal, and at the same time assist the tie-rods in their duty. These braces are formed of round-iron, $1\frac{3}{8}$ inch in diameter, secured at top by bolts passing through the linking-plates, and at bottom by wedges, so as to give an opportunity of tightening them up if required.

Each compartment of principals is thus separately trussed and tied, and the whole made fast at the extremities by passing a strap or stirrup iron round the back of a metal chair, in which each end of the girder rests, and to which it is bolted at the side; the jaws of this stirrup-iron are attached to the extremities of the rods by wedges.

The ends of the principals are fixed in cast-iron chains resting on one side of a metal pillar, and on the other on the wall, or upon the box-beam; those upon the pillars are cast upon the upper cap, and those upon the wall and box-girder rest upon two rollers, which can travel a space of 3 inches upon a metal plate, so as to admit of expansion and contraction.

The purlins are each formed by a combination of three T irons, the centre T iron running straight from principal to principal, and those at the sides branching off at 5 feet from each end, so as to strut the girder in three points. The purlins are secured to the deck-beam by angle plates, fixed on both sides, one limb being fixed to the blade of the purlin, and the other to the deck-beam.

In addition to the lateral trussing which the ribs receive from these purlins, diagonal braces are fixed between each two corresponding struts, connected at the top with the purlins, and at bottom with the linking-plates, by bars of their own scantling; thus the ribs are all braced together, and a firm and rigid mass of framing, formed to carry the covering.

The box-beam, upon which a portion of one side of the roof is supported, is 63 feet 4 inches long; 3 feet 2 inches deep at the ends; and 2 feet 6 inches at the centre, the versed sine being 8 inches. The upper chamber is 20 inches wide, and 8 inches deep, and the body is $13\frac{3}{8}$ inches wide, by 1 foot 10 inches deep. The bottom, $19\frac{3}{8}$ inches wide, is formed of two rows of plates, $\frac{8}{16}$ths inch thick in the middle, and $\frac{6}{16}$ths at the ends. The thickness of all the other plates is $\frac{5}{16}$ths inch. On the opposite side of the roof, 17 cast-iron columns, 21 feet 6 inches apart, serve to support the ribs. The columns are 19 feet high from the base to the cap, and 4 feet 3 inches from the cap to the metal chair. At the bottom they are fastened into stones of 5 tons weight each, at 3 feet below the base. The roof is covered with galvanized corrugated wrought-iron and rough plate-glass. The total cost was £15,000.

A patent was taken out recently by Mr. Nasmyth, for improvements in the construction of fire-proof flooring and roofing.

These improvements consist in constructing floors and roofs of iron plates, which are bent into the form of a segment of a circle, or into a conical, polygonal, or other shape, by the ordinary plate-bending machinery, or by any other suitable means. These bent plates are supported on chord plates, or tension-bars which have their ends bent upwards, whereby the plates are retained in their curved position, when subjected to pressure. The ends of the chords rest upon flanges of cast or wrought-iron girders, above which are cast or riveted knee-pieces, which prevent the bent ends of the chords from springing; or, instead of iron-plates, angle, or T iron, bent into the required shape, and supported upon chords resting upon the flanges of girders, may be employed. Over these curved ribs, iron-plates are bent, with their ends placed underneath the bent-up ends of the chords. The spaces above the iron-plates are filled up, to form the flooring with Portland cement, mixed with broken bricks and other suitable materials. The improved girders are formed by bolting iron plates to the sides and tops of stone arches and chords combined as before. The side plates are made with flanges to support the arches and chords which form the joists, and have also knee-pieces bolted to them to prevent the chords from springing, when the arch is subjected to pressure. The arches and chords may be made of one piece each, or may be made of several pieces, and bolted or riveted together.

Allusion has been made in a previous column, to the various materials used for the covering of roofs, with reference to the different degrees of inclination suitable for them. Thatched roofs have been considered by some to maintain the most equable temperature in the buildings covered by them; keeping out alike the extreme heat of summer, and cold of winter. They are objectionable on account of their harbouring vermin, being easily damaged by wind, and dangerously combustible. The frequent repairs required, make thatch also an expensive material. Besides straw, reeds and heath are sometimes used for thatching, and possess the adavntage of greater durability. Tiles admit heat and moisture more than good slates. Pantiles having no holes for nailing through, are simply hung by ledges, upon laths nailed to the rafters. Plain tiles, laid in mortar, and overlapping so as to be double thickness everywhere, make a very good, though heavy covering. Tiles of a peculiar form, called *hip-tiles*, are used for covering salient angles; and *gutter-tiles*, which are similar to them, but placed with the concave side upwards, in the valleys or receding angles. Slates are laid in various

ways. They are sometimes nailed down on across boarding: or if large, on *battens*, or pieces of wood from two and a half to three inches wide, and three-quarters of an inch to an inch thick, which are nailed to the rafters at intervals regulated by the length of the slates. Lozenge-shaped slating is occasionally used, and has an ornamental appearance, but is easily injured, as there is but one nail through each slate. It is always laid on boarding. For what is called patent slating, the best large slates are selected, and fixed without either boarding or battening, the common rafters being placed at such a width as to come under the joints. The slates are screwed down, the courses over-lapping about two inches. The meeting-joints are covered by fillets of slate, about three inches wide, set in putty, and screwed down; and the hips and ridges are sometimes covered in the same manner, though it is best, in all such cases, to use lead. Patent slating, when well executed, is water-tight, with as low a slope as one in six. In some districts, laminæ of stone are used in lieu of slates or tiles. Shingles, which are like slates, but made of wood, were formerly much used in covering pyramidal steeples, and in roofs of steep pitch. They are still used in the United States, and are usually laid on boarding, in a similar manner to common slates.

Sheets of metal are very convenient for covering domes, and curved angular surfaces generally, and also for flat roofs, or such as have too little slope for slating. Lead is the most common material for such purposes, though copper, iron, tinned-iron, and recently zinc, are also used. Lead terraces, or flats, are commonly laid on boarding or plaster. The joints are sometimes soldered, but the most approved method is to roll or wrap the edges into each other, making allowance for expansion and contraction. A fall of a quarter of an inch in a foot, is sufficient for surfaces covered with sheet metal.

The weight of lead is somewhat against its use for roof-covering; it is used in sheets weighing from 4 lbs. to 8 lbs. per foot super. Copper is much lighter, and is used in sheets weighing about 1 lb. per foot super, but its expensiveness precludes its adoption for general purposes. Zinc is much lighter than lead, weighing from 12 to 20 ounces per foot super; and of late has been very widely employed on this account, as well as because of its cheapness; it forms a very useful covering. Iron galvanized, or coated with zinc, has also been very extensively used for this purpose, for which it is also well adapted. Sometimes it is corrugated, by which it is considerably strengthened, and thus some of the strength of the roof itself may be dispensed with, especially in small spans, where curved roofs of corrugated iron may be safely employed. Tiles of this material also, are sometimes used; they are treated much in the same way as common tiles, being simply nailed to battens or boarding. The following table, giving the weight per square of 100 feet for different kinds of roof-covering, may prove serviceable:—

	Cwts.
Plain tiles	18
Pantiles	9½
Slating	7
Lead at 7 lbs. to foot super	6½
Corrugated iron	2
Copper or zinc at 16 ounces to ditto.	1

Having now given a description of the several varieties of roofs covering a square or rectangular plan, it may not be improper to give a few examples of domes, and show how they may be constructed under various circumstances. If the dome to be constructed be on a circular plan, with no lantern above, the ribs may be built in the following manner, with planks of convenient lengths, in three or more thicknesses. Having ascertained the length of the ribs, and the number of pieces in that length, and having properly shaped all the pieces to the curve, the middle piece at the bottom may be one of these lengths; to each side may be joined two other pieces, one reaching to a third of the middle piece, and the other to two-thirds from the bottom, so that by continuing with planks of the whole length to the other extremity of the rib, the middle thickness will always be covered two-thirds from the bottom on one side, and one-third on the other; the deficiency at the top must be filled up with pieces, one of a third, and the other of two-thirds, as at the bottom; the whole being well bolted together, and strapped across the joints, will be nearly as strong as a solid rib.

Plate VIII. *Figure* 1, shows the manner of constructing this kind of dome; No. 1 being the semi-plan; No. 2, the elevation; No. 3, the manner of building the rib. In domes of this kind, it may sometimes be necessary to discontinue the ribs, that the spaces may be more equally divided for the horizontal ribs. It is evident that a dome built in this manner, may be carried to almost any extent, provided it have a sufficient number of horizontal ribs. Of this construction is the Halle du Blé, at Paris, of 200 feet in diameter, the invention of a judicious carpenter, the Sieur Molineau, a man of little scientific education, but of considerable mechanical experience. Being convinced that a very thin shell of timber might not only be so shaped as to be nearly in equilibrio, but that, if well connected with horizontal ribs, it would have all the requisite stiffness, he presented his scheme to the magistracy of Paris. The grandeur of the idea pleased them but they referred it to the Academy of Sciences. The members, who were competent judges, were struck with the justness of M. Molineau's principles, and astonished that a thing so plain, had not become familiar to every house-carpenter. It quickly became a universal topic of conversation, dispute and cabal, in the polite circles of Paris. But the Acadamy having given a favourable report of their opinion, the project was immediately carried into execution, and soon completed, and now stands as one of the greatest exhibitions in Paris. The circular ribs, which compose this dome, consist of planks 9 feet long, 13 inches broad, and 3 inches thick, made in three thicknesses, as in that already described. At various distances, these ribs are connected horizontally by purlins and iron straps, which make so many hoops to the whole. When the work had reached such a height, that the distance of the ribs was two-thirds of the original distance, every second (now consisting of two ribs, very near each other,) was discontinued, and the void glazed. A little above this, the heads of the ribs are framed into a circular ring of timber, which forms a wide opening in the middle, over which is a glazed canopy, or umbrella, with an opening between it and the dome, for allowing the heated air to get out. All who have seen this dome agree in describing it as the most beautiful and magnificent object they ever beheld.

The only difficulty in the construction of wooden domes is when they are loaded in the upper part by a heavy lantern, or cupola. Such a dome as has been described would be in danger of being crushed inwardly; the most effectual method of preventing which, is by making the ribs in the form of trusses, with an inclined timber extending from the base of the dome to the bottom of the lantern, connecting the two extremities of the exterior side, forming as it were the base of a truss in a common roof, and acting contrary to the nature of a tie-beam; they resist the vertical pressure of the lantern, without having any tendency to burst out the sides by acting entirely longitudinally on the wall-plate. In order

to secure the lantern, horizontal braces are fixed from the bottom of the lantern to the middle of the principal braces under the joggles, so that the whole is resolved into triangles, which are all immoveable at the angles. The wall-plates should be framed as the ribs of a dome constructed as in the last example.

When a dome is to support a heavy cupola of stone, such a construction as that of the cathedral of St. Paul's, London, may be employed. *Figure* 3, No. 1, exhibits the truss of this dome, taken from accurate measurement. A *a a* A, a dome of brick, two bricks thick, which, as it rises every five feet, has a course of strong bricks 18 inches long, bonding through the whole thickness. B *b b* B is a cone, built with bricks 1 foot 6 inches in thickness, for supporting the heavy cupola above, of Portland stone, which is 21 feet in diameter and near 61 feet high, and also the timber-work of the dome. The horizontal, or hammer-beams, c c, &c. are curiously tied to the corbels, D, D, D, &c. with iron cramps, bedded into the corbels with lead, and bolted to the hammer-beams. No. 2 shows more particularly the manner of tying the hammer-beams to the corbels.

This dome is boarded from the base upwards, and the ribs are therefore fixed horizontally, having their sides in planes tending to the centre of the dome. The contour of the dome is formed of two circular segments, which meet in the axis like a pointed arch. The scantlings of the curve rib of the truss are 10 inches by 11½ at the bottom, and 6 inches by 6 at top. It has a very strong double iron chain, linked together at the bottom of the cone, and several other less chains between that and the cupola. This dome was turned upon a centre, supported without standards from below. As every story of the scantling was circular, and the ends of the ledges meeting like so many rings, and truly wrought, it supported itself; and as it was both centering and scaffolding it remained for the use of the painter, there being a space of twelve feet between it and the dome. This machine, it is said, was original of its kind.

A description of a dome constructed mainly of cast-iron girders, over the cathedral of St. Isaac, St. Petersburg, will be found under the article Dome, to which we must refer for further information on the general subject, as well as to Curb Roof, Vaulting, Mechanical Carpentry, &c.

Before concluding this article, we must state that we are much indebted for the descriptions, &c. to *Tredgold's Carpentry*, the *Transactions of the Institution of Civil Engineers*, the *Builder*, and other similar works.

Roof, *Hipped*, see Hipped Roof.

ROOFING, in rural economy, a word sometimes applied provincially to the the ridge-cap of thatched roofs. It also signifies any sort of material employed in forming the roof of a building, whether in the framework or covering. In the business of roofing farm or other buildings, the chief circumstance necessary to be attended to, is that of tying the two side-parts well together, and in a safe manner, by means of the wall-plates and binding-beams; especially in those erections which are of the longer kind, without any cross-walls to stiffen and support them. It has been remarked, that it is generally for want of attention to these matters that farm-buildings, as well as those of other sorts, are so frequently seen propped up with shores and buttresses; or fallen to the ground half a century sooner, perhaps, than they would have done under a better and more judicious management. And it ought, indeed, to be a general principle, or line of conduct, which every careful and intelligent manager should follow in erecting such buildings;—a principle which is equally applicable to the other parts, as well as the timber and the covering;—which is, that of sparing no requisite expenditure, as a few shillings, or pounds, of additional cost in the first instance, may be the saving of ten times the sum in the end.

In the work of repairing buildings of this nature, the roofing claims equally the regard of the manager, with the foundations and other external parts. But the inside works, in all cases, more commonly and properly demand the notice of the occupiers.

ROOM, see Apartment, and Building.

ROSE, an ornament applied to the centre of each side of the abacus of the Corinthian capital.

ROSE WINDOW, a circular window, divided into lights by mullions or tracery branching from the centre, and disposed in a variety of different patterns. Windows of this kind are also termed Catherine-wheel and marigold windows.

ROSTRUM (Latin, signifying *a bird's beak*, or *the prow of a ship*), a part of the Roman forum, where in orations, pleadings, funeral harangues, &c. were delivered.

The rostrum was a kind of chapel taken out of the forum, and furnished with a suggestum, or eminence, called more particularly *the rostrum*, where the orators stood to speak.

It was adorned, or, as Livy says, built, with the beaks of ships taken from the people of Antium, in a naval engagement; whence the name.

There are two kinds of rostra; *rostra vetera* and *rostra nova*. The latter was erected by Augustus, and decorated with the prows of vessels which he took at the battle of Actium. The first were those already described.

ROTONDO, or Rotunda (from the Latin *rotundus*, round), a popular term for any building that is round both within and without, whether it be a church, hall, saloon, vestibule, or the like.

The most celebrated rotondo of antiquity is the Pantheon at Rome, dedicated to Cybele and all the gods, by Agrippa, son-in-law of Augustus; but since consecrated, by pope Boniface IV., to the Virgin and all the saints, under the title of Sta. Maria della Rotondo.

The chapel of the Escurial, which is the burying-place of the kings of Spain, is also a rotondo; and, in imitation of that of Rome, is also called Pantheon.

ROUGH-CAST, or Rough-Casting, see Plastering.

ROUND CHURCH, this appellation is given to a few churches which exist of a peculiar construction, being erected on a plan either simply circular, or circular with a rectangular projection: the circular portion in both cases being that which forms its peculiarity. There are only four such structures in England—the Temple Church, London, which is the largest and most magnificent; the Church of the Holy Sepulchre at Cambridge; one with the same dedication at Northampton; and a small church at Little Maplestead, in Essex. In all these, the round or circular portion bears evidence of greater antiquity than the other parts of the edifice: and there can be no doubt but that the latter are more recent additions to the original structure, which for the most part are employed as a choir, the circular part being retained as the nave. The round consists generally of two, sometimes of three stories, the upper stories being of less diameter than the lower one, and supported on massive piers and arches of Norman-work, by which an aisle is formed all round the interior, between the arcade and the external wall: above the arcade is a triforium, and above this again a clerestory, the roof above being vaulted.

It was at one time held that such buildings had been originally constructed by the Jews for synagogues; but this mistake is now exploded, and it is universally allowed that they were built by the Knights Templars, or Hospitallers, who were engaged in the Crusade to recover possession of the Holy Sepulchre at Jerusalem out of the hands of the infidels, and that the

peculiar form was copied from that building. That the form of the church erected over the Holy Sepulchre by the empress Helena was of a circular form, there seems to be every reason to believe, for we have the evidence of written testimony as well as the form of the existing building; and although, no doubt, this has been rebuilt and much altered, by additions and otherwise, since the time of Constantine, still there is sufficient reason to satisfy us that its general form has not been departed from. It would seem very natural, too, that the Crusaders, when they returned from the East, and began to erect new churches, should adopt that form which they had seen employed in the building, for the defence of which they had undergone such labours; the novelty of the form, too, would be likely to attract their attention, and lead to their emulation of it. When, in addition to this, it is considered that no less than two out of the four churches are dedicated under the name of the Holy Sepulchre, there can be little question as to its origin. Further, a third is named the Temple Church; and there is evidence that it was consecrated by Heraclius, bishop of Jerusalem, when he came to England to ask subsidies for carrying on the Crusade; and there was never any question as to its erection by the Knights Templars, who were especially associated for the defence of the Holy Sepulchre at Jerusalem.

Two of these round churches—the Temple, London, and St. Sepulchre's, Cambridge—have, within these last few years, been very creditably restored; especially the former, on which no expense has been spared to restore it to its pristine splendour; it is one of the most spirited and liberal restorations which have been attempted, and reflects great honour upon those by whom it was carried into effect. The second has been also very well and carefully restored by the Cambridge Camden, now the Ecclesiological Society; but it is to be regretted that the effect of the restoration has been partially destroyed by the bigoted introduction of some ornamental accessories, which are totally misplaced in such a building.

ROUND TOWERS. This term is applied to a particular class of towers built upon a circular plan, which are found in considerable numbers in Ireland, and almost exclusively in that country. They are evidently of great antiquity, and have long been a subject of antiquarian dispute. Mr. Petrie has, within the last few years, published a very elaborate work upon the subject, upon which he brings to bear very considerable knowledge and a clear judgment. His general description of the towers is as follows:—

They are rotund, cylindrical structures, usually tapering upwards, and varying in height from 50 to perhaps 150 feet; and, in external circumference, at the base, from 40 to 60 feet, or somewhat more. They have usually a circular projecting base, consisting of one, two, or three steps or plinths, and are finished at the top with a conical roof of stone, which frequently, as there is every reason to believe, terminated with a cross formed of a single stone. The wall towards the base is never less than 3 feet in thickness, but is usually more, and occasionally 5 feet, being always in accordance with the general proportions of the building. In the interior they are divided into stories varying in number from four to eight, as the height of the tower permitted, and usually about 12 feet in height. These stories are marked either by projecting belts of stone, set-offs or ledges, or by holes in the wall to receive joists, on which rested the floors, which were almost always of wood. In the uppermost of these stories the wall is perforated by two, four, five, six, or eight apertures, but most usually four, which sometimes face the cardinal points, and sometimes not. The lowest story, or rather its place, is sometimes composed of solid masonry, and when not so, it has never any aperture to light it. In the second story, the wall is usually perforated by the entrance-doorway, which is generally from 8 to 30 feet from the ground, and only large enough to admit a single person at a time. The intermediate stories are each lighted by a single aperture, placed variously, and usually of very small size, though, in several instances, that directly over the doorway is of a size little less than that of the doorway, and would appear to be intended as a second entrance.

In their masonic construction, they present a considerable variety; but the generality of them are built in that kind of masonry called spawled rubble, in which small stones, shaped by the hammer, in default of suitable stones at hand, are placed in every interstice of the larger stones, so that very little mortar appears to be intermixed in the body of the wall; and thus the outside of spawled masonry, especially, presents an almost uninterrupted surface of stone, supplementary splinters being carefully inserted in the points of the undried wall.

His conclusion, with respect to the use to which such towers were put, and also as to their date and origin, is:—

1. That the towers are of Christian and ecclesiastical origin, and were erected at various periods between the fifth and thirteenth centuries. 2. That they were designed to answer, at least, a twofold use, namely to serve as belfries, and as keeps or places of strength, in which the sacred utensils, books, relics, and other valuables, were deposited, and into which the ecclesiastics, to whom they belong, could retire for security in cases of sudden predatory attack. 3. That they were probably also used, when occasion required, as beacons and watch-towers.

These conclusions, which have been already advocated, separately, by many distinguished antiquaries, among whom are Molyneux, Ledwitch, Pinkerton, Sir Walter Scott, Montmorenci, Brewer, and Otway, will be proved by the following evidences:—

For the first conclusion, namely, that the towers are of Christian origin:—

1. The towers are never found unconnected with ancient ecclesiastical foundations. 2. Their architectural styles exhibited no features or peculiarities not equally found in the original churches with which they are locally connected when such remain. 3. On several of them Christian emblems are observable, and others display in the details a style of architecture universally acknowledged to be of Christian origin. 4. They possess invariably architectural features not found in any buildings in Ireland, ascertained to be of Pagan times.

For the second conclusion, namely, that they were intended to serve the double purpose of belfries and keeps, or castles, for the uses already specified:

1. Their architectural construction, as will appear, eminently favours this conclusion. 2. A variety of passages, extracted from our annals, and other authentic documents, will prove that they were constantly applied to both these purposes.

For the third conclusion, namely, that they may also have been occasionally used as beacons and watch-towers:

1. There are some historical evidences which render such an hypothesis extremely probable. 2. The necessity which must have existed in early Christian times for such beacons and watch-towers, and the perfect fitness of the round towers to answer such purposes, will strongly support this conclusion.

These conclusions, or at least such of them as presume the towers to have had a Christian origin, and to have served the purpose of a belfry, will be further corroborated

by the uniform and concurrent tradition of the country, and by authentic evidences relating to the erection of several of the towers, with the names and eras of their founders.

A description of one or two of these towers will assist in giving an idea of their varieties and general character. That at Monasterboice, near Drogheda, is 110 feet high and 17 in diameter; the thickness of the wall is 3 feet 6 inches. The ancient church, which is close to it, is now in ruins. In the churchyard are two very old and curious crosses; one about 18 feet high, covered with sculpture, is called St. Boyne's cross, and is esteemed the most ancient religious relic in Ireland. The round tower at Drumisken, in Louth, is 130 feet high; and that of Kildare 133 feet high and 18 in diameter. The walls of the latter are $3\frac{1}{2}$ feet thick, and are built of fine white granite, to about 12 feet from the ground.

Of the two round towers in Scotland, that at Brechin consists of sixty regular courses of hewn stone, of a brighter colour than the adjoining church; it is 85 feet high to the cornice, whence rises a low pointed roof of stone, with windows, and a vane at the top. The other tower at Abernethy is 75 feet high, and like that of Brechin, is about 48 feet in external circumference. On the front of the tower at Brechin are two arches, one within the other, in relief. On the point of the outermost is a crucifix, and between both, towards the middle, are figures of the Virgin Mary and St. John, the latter holding a cup with a lamb. The outer arch is adorned with knobs, and within both is a small slit or loop; at the bottom of the outer arch are two beasts, couchant, one of them, by its proboscis, is evidently intended for an elephant.

There are some few round towers in France, which some antiquaries are inclined to think similar in origin and employment. The French, however, are unlike the Irish towers. Those of the former are of various figures, principally octagonal, and of moderate heights. The tower of Quineville, called Cheminée de Quineville, is one of these. It is situated within eight leagues of Cherbourg, is hollow throughout, having neither stairs nor floors. It consists of a base, circular within, and 17 feet high, constructed in that style called by the Romans *opus reticulatum;* above this is placed a cylindrical column $11\frac{1}{2}$ feet in height and 20 feet in circumference. The external face is ornamented with Corinthian and Tuscan pilasters supporting an entablature, above which rises a dome, roofed in the form of a truncated cone. Some think that it has served as a pharos, others as a belfry. But it is neither within view of the sea, nor near to any church. There are, however, in France, isolated towers in the vicinity of churches. They belong to the middle ages. In the cemetery of the Innocents' at Paris, is one of an octagon form, surmounted by a dome; it is 44 feet in height and 12 feet in diameter. At Mouthran, near Martignon, is another octagon, 35 feet high and 16 in diameter. The door is 8 feet from the ground. In the cloister of the Monastery des Dames, at Fontevrault, is an ancient tower 76 feet in height and 20 feet in diameter. For our own part, we are not of opinion that these towers, or at least all of them, are of the same origin as those in Ireland.

RUBBLE-WORK, a rough, irregular kind of masonry.

RUDENTURE, (from the Latin, *rudens*, a rope,) the figure of a rope, or staff, sometimes plain, sometimes carved; with which a third part of the fluting of columns is frequently filled up. It is by some called a cabling; and the columns, whose flutings are thus filled, they call rudented or cable columns. There are also rudentures in relievo, laid on the naked of pilasters, not fluted; an instance of which we have in the church of S. Sapienza at Rome.

RUDERATION, (from the Latin, *ruderatio*,) in building, a term used by Vitruvius for laying a pavement with pebbles or little stones. To perform the ruderation, it is necessary that the ground be first well beaten, to make it firm, and to prevent its cracking. Then a stratum of small stones is laid, to be afterwards bound together by mortar made of lime and sand, called by Vitruvius *statumen*. If the sand be new, its proportion to the lime may be as three to one; but if dug out of old pavements, or walls, as five to two.

Ruderation, Davilier observes, is used by Vitruvius, lib. vii. cap. 1, for the coarsest and most artless kind of masonry; where a wall is, as it were, cobbled up.

RUINS, (from the Latin *ruina*,) a term particularly used for magnificent buildings fallen to decay through lapse of time, and of which there only remains a confused heap of materials. Such are the ruins of the Tower of Babel, or the Tower of Belus, two days' journey from Bagdad, in Syria, on the banks of the Euphrates; which are now no more than a heap of bricks cemented by bitumen; and of which we only perceive the plan to have been square. Such also are the ruins of a famous temple, or palace, near Schiras in Persia, which the antiquaries will have to have been built by Ahasuerus; and which the Persians now call Tchelminar, or Chelminar; *q. d.*, the forty columns; because there are so many columns remaining nearly entire, with traces of others; a great quantity of basso-relievos, and unknown characters, sufficient to show the magnificence of the antique architecture. The ruins of Palmyra may also be reckoned in the class of famous ruins.

RULE, or Ruler, (from the Latin, *regula*,) a very simple instrument, ordinarily of hard wood, thin, narrow, and straight, serving to direct the drawing of right lines. The rule is of principal use in all the mechanical arts. To prove whether or no it be just, draw a line by it on paper; then turn the rule about, the right end to the left, and apply the same edge this way to the line; if the edge now agree exactly with the line, the ruler is true.

The stone-cutter's rule is usually 4 feet long, and divided into feet and inches. The mason's rule is 12 or 15 feet long, and is applied under the level to regulate the courses, to make the piedroits equal, &c.

Rule, *Parallel*. See Parallel and Instruments.

Rule, is also applied to certain instruments which have other considerable uses besides that of drawing lines. Such are carpenter's joint-rule, Everard's and Coggeshall's sliding-rules, &c.

Rule, *Carpenter's Joint*, an instrument, usually of box, 24 inches long, and $1\frac{1}{2}$ broad, each inch being subdivided into eight parts; on the same side with these divisions is usually added Gunter's line of numbers. On the other side are lines of timber and board-measure, the first beginning at $8\frac{1}{2}$, and continued to 36, near the other end; the latter is numbered from 7 to 36, 4 inches from the other end. The division of the timber-line is formed from a consideration that 1,728 inches make a solid foot, in the following manner:—thus, 9 is so placed against one of the divisions of inches, or parts on the other side of the rule, beginning from the right hand, that its square, which is 81 inches multiplied by that number of inches and parts, must make 1,728 inches; which, dividing 1,728 by 81, must be placed against $21\frac{1}{2}$ from the right-hand; and 10 must be placed against $17\frac{28}{100}$ inches; because 1,728, divided by the square of 10 or 100, gives $17\frac{28}{100}$, &c. But, because a square, whose side is 1,2, &c., to 8 inches, requires more than 24 inches in length, as a multiplier, in order to produce 1,728 inches; and since the length of the rule is only 24 inches, there is a table upon the left end of it, which supplies its defect of length. In

this table, the upper row of figures, viz., 1, 2, 3, 4, 5, 6, 7, 8, denotes inches, or the lengths of the sides of squares; and the second and third rows are the correspondent feet and inches to make up a solid foot. It is made by dividing 144 inches by the squares of 1, 2, 3, 4, 5, 6, 7, 8.

The line of board-measure is thus divided: suppose the division 7 to be marked; divide 144, the number of inches in a square foot, by 7, and the quotient will be $20\frac{4}{7}$ inches; whence the division 7 must be against $20\frac{4}{7}$ inches on the other side of the rule. To mark the division 8, divide 144 by 8, and the quotient, which is 18 inches, must be placed on the line of board-measure against 18 inches on the other side, &c. But because the side of a long square, that is, 1, 2, 3, 4, 5 inches, requires the other side to be more than 24 inches, the whole length of the rule, there is a table annexed, formed by dividing 144 inches by each of the numbers in the upper row, and then each of the quotients by 12 to reduce into feet.

Rule, *Use of the Carpenter's Joint.* The application of the inches in measuring lengths, breadths, &c., is obvious. That of the Gunter's line, see under *Gunter's Lines*, in the article Instruments. The use of the other side is all we need here illustrate.

1. *The breadth of any surface, as board, glass, &c. being given; to find how much in length will make a square foot.*—Find the number of inches the surface is broad, in the line of board-measure; and right against it, on the inches side, is the number of inches required. Thus, if the surface were 8 inches broad, 18 inches will be found to make a superficial foot.

Or, more readily, thus: Apply to the breadth of the board or glass, that end of the rule marked 36, laying it even with the edge; the other edge of the surface will show the inches and quarters of inches which go to a square foot.

To find the content of a given surface: Find the breadth and how much makes one foot; then turn that over as many times as you can upon the length of the surface,and so many feet does the surface contain.

2. *Use of the table at the end of the board-measure.*—If a surface be one inch broad, how many inches long will make a superficial foot? Look in the upper row of figures for 1 inch, and under it, in the second row, is 12 inches, the answer to the question.

3. *Use of the line of timber-measure.*—This resembles the former; for, having learned how much the piece is square, look for that number on the line of timber-measure; the space thence, to the end of the rule, is the length, which, at that breadth, makes a foot of timber. Thus, if the piece be 9 inches square, the length necessary to make a solid foot of timber is $21\frac{1}{3}$ inches. If the timber be small, and under 9 inches square, seek the square in the upper rank of the table, and immediately under it are the feet and inches that make a solid foot. Thus, if it be 7 inches square, 2 feet 11 inches will be found to make a solid foot.

If the piece be not exactly square, but broader at one end than the other, the method is, to add the two together, and take half the sum for the side of the square. For round timber, the method is, to girt it round with a string, and to allow the fourth part for the side of the square. But this method is erroneous; for hereby above a fifth of the true solidity is lost. *See* Sliding Rule, and Timber.

Rule, *Bow. See* Ship Carpenter's Rule.

RULER, *Parallel. See* Instruments.

RUSTIC, a mode of building in imitation of simple or coarse nature, rather than according to the rules of art.

Rustic Chamfered, that when the face of the stones are smoothed and parallel to the surface of the wall, and where the margins are bevelled, at an angle of 135 degrees with the face of the stone; and as the joints are at right angles to the faces, the margins will also be at an angle of 135 degrees with the joints: so that, when two rustics come together, the bevelling, or chamfering, will form an internal right angle.

Rustic Coins, (by Vitruvius called *lapides minantes,*) the stones which are frequently placed at the external angles of buildings, so as to project beyond the naked of the wall; the edges being either bevelled, or the margins recessed in a plane parallel to the face or plane of the wall. The recesses, which are at the joints, have, therefore, three sides; one in the plane of the wall, or parallel thereto; and the other two generally perpendicular to the said plane. Rustic coins were much in use about eighty years ago, particularly in brick buildings. *See* Quoins.

Rustic Frieze. *See* Frieze.

Rustic Order, an order decorated with rustic quoins, rustic work, &c. Felibien says, it is properly where the several parts of the five orders are not exactly observed; but this confounds rustic with Gothic.

Rustic Work is where the stones in the face, &c. of a building, instead of being smooth, are hatched or picked with the point of an instrument.

The most coarse or common kind of rustic work, is that where the edges are simply cut about one-half or two-thirds of an inch round the margin, so as to be in the plane of the wall, or parallel to the said plane, and the intermediate part is broken with the hammer, so that the protuberant parts may project generally about an inch beyond the margin.

The recesses of rustics either run with the horizontal joints only, and have, therefore, the appearance of boards placed at small intervals; and sometimes the recesses run with both the horizontal and vertical joints; and, therefore when disposed in this manner, they have the appearance of projecting tablets.

Rustic Work, *Frosted*, that where the margins are reduced to a plane, parallel to the plane of the wall, and where the intermediate part has the effect of ice, with an irregular surface in protuberant parts.

Rustic Work. *Vermiculated*, that where the margins are reduced to a plane parallel to the face of the wall, and where the intermediate part of the stone, or general surface, is so formed as to have the effect of being eaten by worms.

S.

SACELLUM, in Roman antiquity, denoted a place sacred to the gods, without a roof.

SACRARIUM, a small family chapel in a Roman house, also the place in temples in which sacred things were deposited.

SACRINGE, or SANCTUS BELL, a bell to be found frequently over the eastern or chancel end of a church, supposed to have been rung at the elevation of the host.

SACRISTY, or VESTRY, a room attached to a church, in which the sacred vessels, vestments, and other valuables, are deposited.

SADDLE-BACKED-COPING. Coping weathered on both sides, having two sloping tables on the top, falling from a central ridge.

SAG, or SAGGING, the bending of a body that would be straight in a vertical position; but, when included, or laid horizontallly upon supporters at each end, becomes curved in the middle, from its own gravity: in which case it is said *to sag*.

SAGITTA, in architecture, a name sometimes used for the key-piece of an arch.

SAGITTA, in geometry, a term used by some writers, for the abscissa of a curve.

SAGITTA, in trigonometry, &c. the same as the versed sine of an arc; and so called by some writers because it is like a dart, or arrow, standing on the chord of the arc.

SAINT PETER'S, a celebrated church, at Rome, better known by the name of *Basilica Vaticana*, from its original form, and the Vatican hill, on which it stands, founded by Constantine the Great, over the reputed grave of St. Peter, to whom it was also dedicated. In the days of Paganism, the circus of Caius, afterwards of Nero, stood upon its site; and when Constantine, urged by Sylvester I., bishop of Rome, determined upon erecting this basilica, he destroyed the circus, and began himself to dig the foundation, carrying away, on his shoulders, twelve troughs of the earth, in honour of the twelve apostles. *See* BASILICA. Some of the walls of the circus were, however, permitted to remain, and were used for the basilica, in order to accelerate its completion: a quantity of marble was also taken from various ancient buildings, for its decoration, and it was adorned with a hundred columns. Being magnificently finished, it was consecrated by Sylvester on the 18th November, A.D. 324, and was richly furnished and endowed by Constantine, as it was afterward by other emperors, kings, and particularly by the popes. In 460, or 461, Pope Hilary presented two gold vases, set with jewels, weighing 15 lbs. each, with ten chalices, and twenty-four silver lamps. His successor, Simplicius, gave twelve more silver lamps, and a golden vase, of 16 lbs. weight: Pope Symmachus, about the beginning of the sixth century, presented twenty additional lamps of silver, besides twenty-two arches of the same metal, weighing 20 lbs. each. His successor, Hormisdas, had a silver beam made, of 1400 lbs. weight, to sustain the lamps given by his predecessors, and which burned night and day before the tomb of the apostles. Pelagius I., about the middle of the same century, adorned the tomb with silver, and Gregory I. added a canopy, supported by silver columns, of 180 lbs. each. Honorius I., who was raised to the pontificate in 625, had silver doors made to the basilica, each weighing 975 lbs., and he covered the roof with sheets of gilt metal, taken from the temple of Jupiter Capitolinus. Adrian I., towards the close of the eighth century, had a lamp made, in form of a cross, with 1,360 branches, that were lighted four times a year; and he adorned the tomb, used as a confessional, with 1,328 lbs. of gold. His successor, Leo III., built a tower, then unequalled. In the year 846, the basilica was stripped of all its treasure by the Saracens; but after they had been repulsed, Leo IV. had new doors made, with some basso-relievos of silver; after which, the building seems to have experienced very little alteration till the time of Nicholas III., who ascended the papal chair in 1277. This pontiff adorned it with mosaic-work, and engaged Giotto to execute many paintings for it. He also erected a magnificent habitation, called the *Canonica*, for a chapter of canons, successors of the monks of four monasteries, who had formerly officiated in this temple, by turns, day and night. This Canonica has since been pulled down, to make room for the modern basilica.

About 1,200 years from its foundation, this costly edifice began to exhibit symptoms of considerable decay; and, in 1506, Pope Julius II. began the new basilica, by enclosing all the old one. The first architect engaged in this undertaking was Bramante (see BRAMANTE), who, dying in 1514, was succeeded by Raphael d'Urbino, with others; he dying in 1520, the building was prosecuted by Baldassare Peruzzi. The troubles during the pontificate of Clement VII. caused a suspension of the work; nor was it resumed till 1546, when Paul III. employed Sangallo to carry it forward; but he dying the same year, the work was committed to the celebrated Michael Angelo Bonarotti (see BONAROTTI), who converted the design into the form of a Greek cross, and executed the design for the cupola. Bonarotti lived to see the building carried to the height of the tambour; and, on his death, which took place in 1564, he was succeeded by Giacomo Barozio da Vignola, till 1573, when Giacomo della Porta, assisted by Domenico Fontana, in the pontificate of Sixtus V., raised up the wonderful cupola from Bonarotti's model; and, to complete the small cupola, he added a ball of metal, as a supporter to the cross; the concavity of which ball contains commodiously thirty-two persons sitting. This building had been sixty-seven years in hand, under the superintendence of seven architects, and during the reigns of twelve popes.

In 1606, the plan of this building was changed from a Greek cross to a Latin one, by pope Paul V., who also erected the portico with the grand front, after a design of Carlo Maderno.

This church surpasses all the most celebrated buildings, ancient or modern, not only in its size, which is immense, but in the excellency of its construction, within and without, and in the admirable works in marble, mosaic, metal, and gilt stucco, with which it is adorned.

At the foot of the grand ascent to the church are the statues of St. Peter and St. Paul, executed for the old basilica in the pontificate of Pius II., by Mino da Fiesole. The basso-relievo on the front, under the benediction gallery, representing our Lord committing the keys to St. Peter's care, is by Malvicino. The portico is ornamented with statues of the first popes, who suffered martyrdom, surrounded by festoons, angels, and gilt stucco; the performance of Algardi: the marble columns, of surprising magnitude, are from the origi-

nal temple. On the right is a marble equestrian statue of the founder, Constantine the Great, in the attitude of observing the celebrated cross in the heavens, with the motto, *In hoc signo vinces :* it is the work of Cav. Bernini. In the four niches of the vestibule of the portico are as many statues, viz., Hope, by Livoni; Faith, by Rossi; Charity, by Ludovisi; and the Church, by Frascari. At the other end, on the left, is the equestrian statue of Charlemagne, as defender of the church, by Agostino Cornachini. In the vestibule, on the near side, are four other statues, viz., Prudence, by Livoni; Fortitude, by Ottone; Justice, by Rossi; and Temperance, by Rafaelli. Over the middle door is a large basso-relievo, in marble, of Christ committing his flock to St. Peter, by Bernini: and opposite to it is the celebrated *Navicelli*, or small ship, painted by Giotto, about the year 1300: this was formerly placed in the yard of the square portico, as a symbol of the Catholic Church, agitated, but not overwhelmed, from the tempest of many persecutions.

The entrance to the basilica is by five doors: that in the middle is metal, and was executed by order of Pope Eugenius IV., at Constantinople, by Filareto; its ornaments represent the martyrdom of St. Peter and St. Paul, and some deeds of the pope who ordered it.

The fifth door called *Porta Santa*, or holy door, is only opened in the jubilee year; and under the portico, near this middle door, the first bull for the jubilee, composed by Boniface VIII., is inscribed upon marble. Near the Porta Santa are two other inscriptions; one consisting of verses made by Charlemagne, in 795, in praise of Pope Adrian I.; the other describing the donations of Pope Gregory II. to this church, of olive grounds and other lands, for supplying the lamps at the sepulchre of the Apostles.

On first entering this vast temple, the imagination is raised with the expectation of beholding exquisite beauty and elegance; but the admiration it excites does not equal its fame, till the spectator begins to observe its several parts. On drawing near to one of the basins of holy water, on the first pilaster, the marble cherubim, that support it, appear at first regular and natural; but afterwards they are found to be gigantic, and almost out of proportion; they are the work of Livoni, Moderati, Rossi, and Cornachini. The doves, of marble, with olive-branches, that seem at first as if they could be touched by the hand, prove, on a nearer approach, to be very high, and appear to be flying still higher: an effect observable in most of the other works.

The middle aisle has a magnificent marble pavement, and the ceiling is grandly ornamented with gilt stucco, worked in grotesque with fruits, by Provenzale, by order of Pope Paul V., whose arms are in the centre, in mosaic; and every part is embellished with beautiful marble columns, and excellent basso-relievos, among which are fifty-six large medallions, with the portraits of as many sainted popes, sculptured by Nicolo Salé, a Frenchman, from designs of Bernini. Fixed against the pilasters are two remarkable stones, on one of which, it is said, Pope Sylvester I. divided the bodies of St. Peter and St. Paul; and, on the other, many martyrs were tortured and put to death. There are also two round black stones, which the Gentiles tied to the feet of the martyrs when on the *eculeo*, an instrument of torture in the form of a horse. The bronze statue of St. Peter, sitting, in the act of giving his benediction, was executed by order of Leo I., from the Jupiter Capitolinus, as an acknowledgment of the liberation of Rome from the persecution of Attila the Hun.

In the centre of the cross aisle, under the grand cupola, is the altar, called the *Confessional of the Apostles;* and under it is the ancient altar, turned toward the east, beneath which are said to be half the body of St. Peter and half that of St. Paul, with those of the early sainted popes. Here was the Vatican cemetery, where Anacletes first buried the body of St. Peter: and a small temple was built over it, which was afterwards pulled down, by order of the emperor Heliogabalus, to enlarge the passage for the triumphal cars. Around this shrine were formerly a vast number of lamps, with wicks of asbestos, continually burning balsam. Pope Calixtus II., in 1119, repaired and adorned it with costly marble, and consecrated it in the presence of the fathers of the general council convoked by him, and consisting of about a thousand bishops. It suffered no change, though the church was rebuilt in the interval, till the time of Clement VIII., who, about the year 1600, without removing any part of it, had it erected over the present altar. Paul V., a few years afterwards, having enlarged the basilica, as already noticed, adorned this confessional with precious marble, jasper, four alabaster columns, the statues of the two apostles, in bronze gilt, with other ornaments of the same material; and erected two noble descents, for the convenience of devotees approaching nearer the sanctuary to pray, around which one hundred and twenty-two silver lamps are continually burning. Urban VIII., at an expense of 100 000 crowns for workmanship alone, employed Bernini to erect a canopy of bronze over this shrine, supported by four twisted columns of the same metal, ornamented with very fine cherubim, modelled by Famingo, and partly gilt; with other remarkable works cast by Rossi.

The height of this canopy, including the cross on its top, is 124 palms; 186,392 lbs. of metal were consumed in making it, and, for the gilding, 46,000 crowns of gold.

The grand cupola is said by some to equal that of the ancient Pantheon; but others insist that it exceeds it by 37 palms in breadth, and 30 palms in height; being in magnitude 200 palms. The ball is 12 palms in diameter, and the cross is 25 feet in height, cast in bronze. The inside of the cupola is covered with mosaic work, from the cartoons of Cav. d'Arpino. The cherubim and flowers are by Roncalli and Provenzale; the evangelists, St. Matthew and St. Mark, by Nebbia; and St. Luke and St. John, by Vecchi. In the pilasters, Bernini opened four galleries, for exhibiting the sacred relics kept within the tabernacles. In that over the statue of Sta. Veronica is said to be part of the holy cross; the spear that pierced the side of our Lord, (presented by Sultan Bajazet II. to Pope Innocent III.); and the veil of Veronica, on which the face of Christ is impressed, and brought by her to Rome; but to these precious remnants no one is permitted to ascend, except the canons, without special leave of the pope. Over the statue of Sta. Helena, are many other relics, which are publicly exhibited at various times of the year. The eight columns in these galleries are said to have stood originally in Solomon's temple. The four marble statues in the niches are each twenty-two palms in height; that of Sta. Veronica is by Mochi; that of Sta. Helena by Bolgi; that of St. Andrew, by Quesnoy Fiamingo; and that of St. Longinus by Bernini; which last also executed the angels and other ornaments in the galleries. Against the pedestal of each statue is an altar-piece in mosaic, taken from the paintings of Andrea Sacchi.

Near these statues is the descent to the Grotto Vaticani, or the old church, into which women are only permitted to enter on Whit Sunday, when men are prohibited to approach. Here is the sepulchre of the apostles, erected by Anacletes, and among the ornaments of the high altar, are a statue of St. James, a Poliandro col pro Christo, containing many bones found in various piles of marble; and a chapel, with an image of God the Father, in marble.

On leaving this chapel is observed the old tribune, of mosaic, repaired by Giotto; the verses were cut on the frieze

of the cornice, and the large cross was on the top of the ancient front. In the chapel of the blessed Virgin are the statues of St. Matthew and St. John; two sepulchral urns; various basso-relievos; part of a bull of Gregory III. inscribed on marble; besides other curiosities, too numerous to be particularized.

In the front of St. Peter's church towards the east, in the ancient camp, or valley, where the gentiles performed the Vaticini, and prepared for the triumphal processions, is the piazza of the Vatican basilica, in the form of an amphitheatre, which, for extent, magnificence, the distribution and elegance of the porticos, columns, statues, and fountains, astonishes the beholder, and appears to be the *ne plus ultra* of human art and genius. This was the work of Pope Alexander VII. from designs by Bernini, about the middle of the 17th century. The colonnades are of the Doric order, consisting of three hundred and twenty large stone columns, distributed into tetrads, and forming a street in the centre for processions, with walks at the sides for spectators. They are covered, and surrounded with cornices, on which, for greater ornament, are erected a stone balustrade, and one hundred and thirty statues of saints of both sexes, whose relics are preserved in the church, with those of the various founders of the religious orders.

In the centre of this piazza is the celebrated Egyptian obelisk, the only one of its kind that has wholly escaped the ravages of barbarous hands, and the injuries of time. It is of plain red granite, 113½ palms in height, all of a single piece; or, from the base, including the pedestal and cross, 180 palms, the cross alone being 10 palms. This monument, of ancient but uncertain date, is said to have been one of two obelisks dedicated to the sun in Heliopolis, the On of holy writ, by Nuncorius, called also Pheron, son of Sesostris, king of Egypt, on occasion of his recovering his sight, after a blindness of ten years; where it remained till the reign of the emperor Caligula, who, according to Pliny, had it removed to Rome, in the third year of his reign, and set up in the Vatican circus. When Constantine the Great destroyed the circus, the obelisk was left standing, and it remained neglected upwards of one thousand two hundred and fifty years, till the pontificate of Sixtus V., who was made pope in 1585, by which time it was buried to the top of the base in the accumulated ruins and rubbish. Sixtus ordered it to be cleared to its foundation, and employed the architect Dominico Fontana, who, on the 10th of September, 1586, with the labour of eight hundred men, and one hundred horses, removed it to its present situation, and set it up on two large blocks of granite, brought from Egypt at the same time with itself, and which serve for the pedestal, supported by a base of white marble. On the angles are four lions of metal, appearing to sustain the obelisk, cast from a model of Bresciano. The same pope dedicated it in honour of the true God, and, instead of the large metal ball, that was originally on the top, he placed his own arms, consisting of three mounts and a star, and above them a metal cross; which last, being injured by lapse of time and the weather, was taken down in 1740, and being repaired, a particle of the wood of the holy cross was inserted into it, and various indulgences have since been granted to those who, in passing by, have saluted it with a *Paternoster* or an *Avemaria*. The removal of this obelisk to its present situation, was first contemplated by Pope Nicholas V., who intended to have it sustained upon four colossal statues of the evangelists; but his death, in 1445, prevented the execution of his design.

On the right of the obelisk is a fountain, made by Paul V. early in the seventeenth century; and on the left is another, by Clement X., about the year 1671. They are both admirable works, as well for the copious supplies of water they throw up, as for their basins of the finest Egyptian granite each cut out of one solid block.

For a view of the dimensions of this church, compared with those of St. Paul's, London, the reader is referred to page 674 of this volume.

SALIANT, (from the French, *saillant*, of *sailler*, to project or advance outwards; derived from the Latin, *salire*, to leap) in fortification, a projecting part.

There are two kinds of angles; the one *saliant*, or such as present their points outwards; the other *re-entering*, which have their points inwards. Instances of both kinds occur in tenailles and star-works.

SALLY, (from the French, *saille*, a jutting out) more commonly termed *projecture*, an expression used respecting the end of a piece of timber, when cut with an interior angle, formed by two planes, across the fibres; in which case the interior angle is called *a sally*, or *bird's mouth*. In this manner the feet of common rafters, and the inclined pieces which support the flying steps of a wooden stair, are frequently cut; as are likewise the lower ends of all inclined timbers, which rest upon plates or beams.

Sally-Ports, or Postern Gates, in fortification, underground passages, leading from the inner to the outer works, such as from the higher flank to the lower, or to the tenailles, or the communication from the middle of the curtain to the ravelin. In every place of arms, there are two sally-ports, each ten or twelve feet wide, for the troops to sally out. In time of a siege, they are shut up with barriers, or gates.

SALOON, (from the French, *salon*, a hall) a grand, lofty, spacious apartment, vaulted at top, and usually comprehending two stories, with two ranges of windows.

The saloon is a grand room in the middle of a building, or at the head of a gallery, &c. Its faces, or sides, are all to have a symmetry with each other; and as it usually takes up the height of two stories, its ceiling, Davilier observes, should be made with a moderate sweep.

The saloon is a state-room, much used in the palaces of Italy, and from thence the mode came to us. Ambassadors and other great visitors are usually received in the saloon. It is sometimes built square, sometimes round, or oval; sometimes octagonal, as at Marly, and sometimes in other forms.

To ascertain the superficies of a saloon, find its breadth, by applying a string close to it across the surface; find also its length by measuring along the middle of it, quite round the room; and multiply these results together for the surface. To find its solid contents, multiply the area of a transverse section by the compass taken round the middle part; subtract this product from the whole vacuity of the room, supposing the walls to go upright all the height to the flat ceiling.

SANCTUARY, the presbytery, or eastern extremity of the chancel eastward of the choir, which was set apart for the officiating priests, and in which the altar was stituated. *See* Chancel.

SAND (Dutch), in mineralogy, a name given to all mineral matter that exists in minute detached grains, and more particularly denominated from the prevailing substance as *silicious sand*, *iron sand*, &c.

Sand is generally formed from the disintegration of hard stones, or rocks, by the agency of water, and the particles of silicious stones, possessing a greater degree of hardness than most other kinds. The use of sand in building is an ingredient in mortar. For this purpose, pit-sand is, of all others, the best; and of pit-sand, the whitest is always the worst. Of river-sand, that found in the falls of water is best, because most purged; and sea-sand is worst of all.

Pit-sand, as being fat and tough, is most used in walls and vaults. River sand serves best for rough-casting.

All sand is good in its kind, if, when squeezed and handled, it crackles; and if, being put on a white cloth, it neither stains nor makes it foul. That sand is bad, which, mixed with water, makes it dirty and muddy, and which has been long in the air: for such will retain much earth and rotten humour. Hence some masons wash their sand before they use it.

The sand of Puzzuolo, De Lorme observes, is the best in the world; especially for maritime buildings. *See* PUZZOLANA.

SAND-STONE, in mineralogy, a stone essentially composed of grains or particles of sand, either united with other mineral substances, or adhering without any visible cement. The grains or particles of sand-stone are generally quartz, sometimes intermixed with felspar, or particles of slate. When the cementing matter is lime, such sand-stones are called calcareous: frequently the cementing matter is oxide of iron intermixed with alumine. The particles of sand in these stones vary greatly in size, some being so minute as scarcely to be visible.

Sand-stone is generally distinctly stratified; and some kinds, which contain a considerable quantity of mica, split into thin laminæ, which are used for slates in some parts of England, particularly in the West Riding of Yorkshire.

The lowest of the principal beds of sand-stone has been called by Werner, and the German geologists, the old red sand-stone. It generally rests on rocks of slate or grey-wacke, and is covered by thick beds of limestone. It is frequently coarse-grained, consisting of particles of quartz, and sometimes of felspar, cemented by iron-shot clay, that gives it the red colour from which its name is derived. According to many geologists, the red sand-stone, which extends on the western side of England, from Penrith in Cumberland to Shropshire, belongs to this formation.

The number and variety of sand-stones in the secondary strata are very great, and the diversity of quality fits them for the various purposes of building-stones, grind-stones, filtering-stones, &c. *See* STONE.

SANGALLO, ANTONIO DE, a celebrated architect, born in the 15th century, in the territory of Florence. His father, Antonio Picconi, was a cooper by trade, and Antonio was brought up to the business of a joiner. Having, however, two uncles, Guiliano and Antonio Sangallo, architects, of considerable reputation at Rome, he placed himself under their tuition, and assumed their name. He soon exhibited considerable talents, and his progress in the art made him known to Bramante, who, in 1512, entrusted to him the execution of several works. He soon obtained employment from some Cardinals; and in the pontificate of Leo X, when his uncle Giuliano quitted Rome, he was appointed his successor as architect of St. Peter's, in conjunction with Raphael. He also manifested great skill as an engineer; and Leo adopted a plan which he gave for the fortification of Civita Vecchia. Under Clement VII. he was employed in enlarging and embellishing the Vatican Palace, and in repairing the fortifications of Parma and Placentia. He is also celebrated for the construction of a remarkable well at Orvietto which had two staircases for the descent and ascent of beasts of burden. He enjoyed the favour of Paul III., who employed him in many important works as architect and engineer; and when Charles V. visited Rome after his Tunisian expedition, Sangallo had the planning of the triumphal decorations with which he was received. The Pauline chapel, and the magnificent staircases by which the chapels of the Vatican communicate with St. Peter's, were of his construction. The grandest effort of his genius was a wooden model of St. Peter's, which, however, was not closely followed. As he was noted for the solidity of his building, he was employed in strengthening the foundations of the Vatican and of the great columns which support the cupola of St. Peter's. Being engaged by the pope to survey the inundations of the lake of Marmora, the heat and the exhalations from the foul water caused a disease, of which he died in the year 1546.

SAP (from the Italian *zappare*, to undermine), in building, a term used when a trench is opened in the ground at the foot of a wall, &c., so as to bring it down all at once for want of support.

To demolish the thick firm walls of old castles, &c, sapping is much the readiest way.

SAP, in the military art, denotes a work carried on under cover of gabions and fascines on the flank, and mantelets, or stuffed gabions, on the front, to gain the descent of a ditch, counterscarp, or the like.

It is performed by digging a deep trench, descending by steps from top to bottom, under a corridor, carrying it as far as the bottom of the ditch, when that is dry; or as far as the surface of the water, when wet.

SAPHETA, more commonly called SOFFIT, in architecture, the board over the top of a window, placed parallel and opposite to the window-stool at the bottom.

SARACENIC ARCHITECTURE. *See* MOORISH ARCHITECTURE.

SARCOPHAGUS (from *σαρκοφαγος*), a sort of stone coffin or grave, in which the ancients laid those they had not a mind to burn.

The word, as derived from the Greek, literally signifies *flesh-eater*; because, at first, they used a sort of stone for the making of these tombs, which quickly consumed the bodies. The quarries from whence they dug it were near a city of Troas, named Assum. They had the faculty to waste away a body, except the teeth, in forty days. This stone resembled a reddish pumice-stone, and had a saltish taste. The ancients also made vessels of it to cure the gout, into which they put their feet, not suffering them to continue there too long.

SASH (from the french *chassis*, a frame), a chequered frame for holding the squares of glass in windows, and so formed as to let up and down by means of pulleys. Sashes are either single or double hung.

SASH-FRAME, the wooden frame in which the sashes are fitted for the convenience of sliding up or down, [illegible]s, as the nature of the apartment to be lighted ma[illegible]u.

When one or both sashes are to be moved vertically, they are commonly equipoised by weights; and the weights are made to run in vertical trunks, or cases, formed in the sides of the frames, which are therefore said to be *cased;* but when the sides are not made hollow for weights, the frame is said to be *solid.* In a sash-frame, the under side of the head is most commonly disposed in the same surface as the soffit, or intrados, of the stone or brick head of the window on the outside; consequently, it partakes of the shape of the head of the window, whether straight or circular. In a cased sash-frame, each case consists of four pieces; the inside piece, on each side, or that next the aperture, is most commonly disposed in the same plain with the jamb of the stone, or side of the aperture, on the outside, the two sides forming parallel planes: these two pieces are called *pulley-pieces*, from their containing the pulleys, over which the ropes pass, by which the sashes and weights are suspended. The other three parts of each trunk are called *linings;* that parallel to the pulley-piece, and next to the jamb, on either side, is called

the back lining; the one next the outside, and parallel to the face of the wall, is *the outside lining;* and the remaining one next to the inside of the room, is denominated *the inside lining.* The best-made sash-frames have the pulley-pieces tongued into the outside and inside linings; the back lining is generally tongued into the outside, and nailed to the edge of the inside lining; on each pulley-piece two channels, of equal breadth, for the edges of the sashes to run in, are formed by nailing a slip of wood round the inner margin of the pulley-piece, and suffering the outside lining to project within it; between which a narrow slip is inserted in a groove, left in the middle of the intervening space. As the edge of this slip is generally rounded, it is called the *parting bead;* and the inner slip, for the same reason, is termed *the inside bead;* while the edge of the outer lining is called *the outside bead.* Within the case, there is also a vertical slip, suspended from the head, and passing longitudinally through the middle of the hollow space, for separating the two weights, which is therefore called *the parting slip.* The head, sill, and inside linings, have generally each a groove next to the inside of the room; the groove in the head and sill is commonly three-eighths of an inch from the edge next to the opening; that in the head is for inserting the edge of the soffit, and that in the sill for receiving the edge of the capping bead, upon the upper edge of the back. The grooves, in the inside lining, are for the edges of the back lining of the boxing; the distance of these grooves from the niner edge of the inside depends on the depth of the boxing, and the distance of each line of hinges from the inner edge of the inside lining, or of that next to the opening. The line of hinges is generally about three-eighths of an inch from the inner edge of the inside lining; so that the shutters, soffit, and capping bead, may have their terminating edges with the sash-frame of the same margin all round; that is, at the same distance as the inner edge of the sash-frame; this, however, is not positively necessary, but may be varied at the discretion of the architect or workman. The line of hinges being determined, the depth of the boxing is found by adding to the thickness of the wall that of the inside finishing, whether of plaster alone, or of lath and plaster (the former requiring about an inch and the latter $2\frac{1}{4}$ inches); and subtracting from the sum, the thickness of the sash-frame, and its distance from the outside of the wall; then, if the remainder be equal to, or exceed half the distance of the hinge-lines, such half distance is the breadth of both the boxing and the shutter; it must, however, be observed, that the outer edge of the shutter must be rebated, as that would prevent the edges of both coming close to the architrave, or margin style which forms the side of the boxing, opposite to the inner lining of the sash-frame, when each shutter consists of one piece only; to remedy this, each shutter must either consist of two folds, *viz.*, a front part, and a back flap; and the breadth of the boxing must be contracted, either by introducing a margin style at the edge of each boxing; or, if one was necessary before, by making it broader; then the thickness of the two folds will be the neat distance of the groove from the line of hinges. If, on the other hand, the remainder, before mentioned, be less than the half distance between the hinge lines, it is the breadth of the boxing; divide the half distance between the hinge lines, by the breadth of the boxing, and the quotient will give the number of folds; and if there be a remainder, there must be one fold more than is shown by the quotient. The aggregate, or sum of all the folds, is the neat depth of the boxing: but, in order to make the folds clear each other and the back of the boxing, add the eighth or tenth part of an inch for each fold. Thus, suppose the wall to be of eighteen-inch brickwork, and the finishing within to be lath and plaster; suppose, also, the breadth of the window to be 4 feet, the sash-frame 6 inches thick, and its distance from the wall 4 inches: then, $20\frac{1}{4}$ inches is the thickness of the wall and finishing; the thickness of the sash-frame and its distance from the face of the wall are, together, 10 inches; this, taken from $20\frac{1}{4}$ inches, gives $10\frac{1}{4}$ inches for a remainder, which is the breadth both of the boxing and of the shutter, because $10\frac{1}{4}$ inches are less than 24 inches, the half distance between the lines of hinges: $10\frac{1}{4}$ is contained twice in 24 inches with a remainder; there are, therefore, three folds, *viz.*, a front fold and two back flaps; suppose the front fold to be $1\frac{1}{2}$ inch thick, each back $1\frac{1}{4}$ inch thick; then $1\frac{1}{2}+1\frac{1}{4}+1\frac{1}{4}=4$ inches; and because there are three folds, add $\frac{3}{8}$ of an inch more, and the depth of the boxing will be $4\frac{3}{8}$ inches. Sash-frames are made in Dublin with half-sills.

Figure. No. 1. Represents part of the frame of a common sash, showing a section through one of the sides, and a part of the plan of the sill.

No. 2 The side of the sash-frame, with the pulley style, and the sections through the sill and head.

No. 3. Part of the elevation of the sash-frame, the inside lining being removed to show the weight.

Figure 2. No. 1. A complete plan of a sash-frame, where the lines are concealed; this, however, does not affect the plan, so as to make it differ from that of common sashes, as shown at *Figure* I, No. 1.

No. 2. The pulley style, exhibiting the pulleys in the middle, instead of being much nearer the top than the middle.

No. 3. Part of the elevation, showing how the line is fixed to the lower sash, and hooked to a piece fixed to the trunk for the purpose.

No. 4. Part of the elevation on the other side, showing the manner of fixing the line to the upper sash, and to the dividing piece.

No. 5. The inside of the sash-frame, with both weights exposed.

SAW, (from the Saxon *saga*, or Danish *sawe*) a thin plate of steel, indented on the edge, for cutting, or dividing wood or soft metals, by a reciprocal change of motion in the hands of the workman, by pushing it from, and drawing it towards him. The cut which it makes, or the part taken away, in a board, is a thin slice, contained between parallel planes, or a deep narrow groove of equal thickness. Saws are of several kinds, as the *pit-saw*, the *bow-saw*, the *ripping-saw*, the *half-ripper*, the *hand-saw*, the *panel-saw*, the *tenon-saw*, the *sash-saw*, the *dove-tailed saw*, the *compass-saw*, and the *hey-hole* or *turning saw.* The teeth of these saws are all formed so as to contain an angle of 60 degrees, both externally and internally, and incline more or less forward as the saw is made to cut transverse to, or in the direction of the fibres; they are also of different lengths and breadths, according to their use. The teeth of a saw are bent alternately to each side, that the plate may clear the wood; and, for this purpose, also, the edge on which the teeth are cut is thicker than the other edge.

The best saws are made of steel, ground bright and smooth. If, in bending the plate of a saw, the resistance be great, and the curvature uniform, it is a proof that it has been evenly ground, and well hammered. Saws intended to cut hard wood, must be so sharpened as to lean more from the perpendicular drawn from the internal angle, to the line passing along the bottom of the teeth, than those which are intended for cutting soft wood.

The *pit-saw* is used by two sawyers, for dividing the trunks of trees into boards of any thickness, or for dividing larger pieces of timber into smaller scantlings.

The *bow-saw* is for cutting the thin edges of wood into curves.

The *ripping-saw* is used for dividing or slitting wood in the direction of the fibres; the teeth are very large, there being eight in three inches, and the front of the teeth stand perpendicular to the line which ranges with the points; the length of the blade is about 28 inches.

The *half-ripper* is also used for dividing wood in the direction of the fibres; the length of this plate is the same as the former, but there are only three teeth in the inch.

The *hand-saw* is used both for cutting the wood in the direction of the fibres, and for cross-cutting; for this purpose, the teeth are more reclined than those of the two former; there are 15 teeth contained in 4 inches. The length of the plate is 26 inches.

The *panel-saw* is used for cutting very thin wood, either in a direction of, or transverse to, the fibres. The length of the plate is the same as that of the hand-saw, but there are only about six teeth in the inch. The plate of the hand-saw and panel-saw is thinner than that of the ripping-saw.

The *tenon-saw* is generally used for cutting wood transversely to the fibres, as the shoulders of tenons. The plate of a tenon-saw is from 14 to 19 inches in length, and the number of teeth in an inch from 8 to 10. As this saw is not intended to cut through the wood in its whole breadth, and the plate would be too thin to make a straight kerf, without being in danger of buckling, there is a thick piece of iron fixed upon the upper edge, called *the back*. The opening through the handle, for the fingers, of this and the foregoing saws, is closed all round; and is therefore called *a double handle*.

The *sash-saw* is used by sash-makers in forming the tenons of sashes: the plate is 11 inches in length. The inch contains about 13 teeth; this saw is sometimes backed with iron, but more frequently with brass.

The *dove-tail saw* is used in dove-tailing drawers. The length of the plate is about 9 inches, and the inch contains about 15 teeth. This plate is also backed with brass. The handles of the two last saws are only single.

The *compass-saw* is for cutting curves upon the surfaces of wood. For this purpose it is narrow, without a back, and thicker on the cutting-edge, as the teeth have no set. The plate is about an inch broad next to the handle, and diminishes to about a quarter of an inch at the other extremity; there are about five teeth in the inch; the handle is single.

The *key-hole* or *turning-saw* is similar to the compass-saw in the plate, but the handle is long, and perforated from end to end, so that the plate may be inserted at any distance within the handle. The lower part of the handle is provided with a pad through which is inserted a screw, for the purpose of fastening the plate in the handle; this saw is used for turning out quick curves, as key-holes, &c.; whence its name.

SAW-PIT, a pit dug under ground for the sawing of timber, the hollow being enclosed with a frame of timber-work for the purpose of placing the timber to be cut by two men, one standing in the pit, and the other on the top of the timber. It is obvious that the top of the timber-frame, from the bottom of the pit, must be something more than the height of a man, and not much raised from the level of the ground, for the convenience of placing the timber over the pit. In pits made for duration, the insides are lined with boarding, brick, or stone-work.

SAWYERS, men whose constant employment is to divide the trunks of trees into boards, or into scantlings of timber of any size. They work in pairs, one man standing on the wood to be divided the other beneath in a pit, made principally for the more easy placing of the timber. The saw having a handle at each end, is drawn up by the man on the top, assisted by the man in the pit, who pushes it upwards; it is then let down chiefly by its own weight, with a small degree of force exerted by both. This operation is continued till the whole cut has been made.

Sawyers most commonly work by the hundred superficial feet, for which they have various prices, according to the hardness or quality of the timber.

SAXON ARCHITECTURE, that style which was practised by the Anglo-Saxons during their ascendancy in this country; a style which is exhibited solely in churches, and other ecclesiastical structures, and prevailed from the time of the conversion of the Saxons, to the Norman conquest.

When the Saxons first obtained possession of the country, they were pagans; a barbarous race, much inferior to their predecessors, the Britons, in the cultivation of the civilized arts. It would appear that they did erect some buildings of importance, as we find Gregory the Great giving permission to St. Augustine to make use of their temples for the purpose of Christian worship; but of what description such buildings were, we have no conception; nor, indeed, are we certain that they did not employ such buildings as they found already erected in the country, rather than erect new ones for themselves. Be this, however, as it may, we are here only concerned with their Christian edifices. Of these, the first, occupied by the missionary Augustine, was one at Canterbury, dedicated to St. Martin, which Bertha, the Christian queen of the pagan king, Ethelbert, had been in the habit of using. This, however, was not a Saxon edifice, but probably a church of the ancient Britons which had escaped destruction by their treacherous allies. In reference to this circumstance, the Venerable Bede tells us—"There was, in the east side, near the city, a church dedicated to the honour of St. Martin, formerly built whilst the Romans were still in the island, wherein the queen, who, as has been before said, was a Christian, used to pray. In this they at first began to meet, to sing, to pray, to say mass, to preach, and to baptize; till, the king being converted to the faith, they had leave granted them more freely to preach and build or repair churches in all places." From this account, it is evident that many churches were erected even in St. Augustine's time, and of the erection of some of these we have authentic records. The first erected was the cathedral church of Canterbury, built on the site of an old Roman church, and which St. Augustine dedicated under the title of Christ's Church. Adjoining to this, was built a house for the bishop, and a little way out of the city a monastery and a church belonging to it, in honour of St. Peter and St. Paul. This last, however, he did not live to finish: it was completed by Lawrence, whom he ordained to succeed him as archbishop, after his death.

It is further evident, from the above quotation, that some churches were then standing, which had been previously erected by the British Christians: of these, St. Martin's is one, and another probably the cathedral, which is supposed by some to have been originally a Roman church, and to have been no more than repaired by Augustine; but whichever be correct, it is certain that a Roman church stood originally on the same spot, and probably that the remains of it at least still existed at the time we are speaking of. It is very likely that the materials of the original fabric were worked up in the new erection.

So wonderful was the success of Augustine, that before his death he was enabled to found two bishoprics, the one at London and the other at Rochester, where, shortly after his decease two cathedrals were erected—that at London

being dedicated to St. Paul, and that at Rochester to St. Andrew, by which names the cathedrals standing on the same sites are still known. At the same date, king Sebert also founded the ancient Abbey of Westminster.

Within thirty years from Augustine's death, Paulinus had succeeded in converting to Christianity, Edwin, the king of Northumbria, and became bishop of that province. His see was fixed at York, where Edwin immediately set about building him a church, which we learn was built of timber, and dedicated in the name of St. Peter. From such humble beginnings arose the splendid cathedral which now adorns that city. This timber-structure was erected previous to the baptism of the king; shortly after that event, however, he took care, by the direction of Paulinus, to build in the same place a larger and nobler church, of stone, within which the smaller building, which he had first erected, was enclosed. During the erection of this building Edwin was assassinated by his pagan subjects, and the church was completed by his successor, Oswald. After this, Paulinus crossed the Humber to preach the gospel at Lincoln, where he succeeded in converting the reeve or governor of the city, who was a man of considerable wealth, and who undertook the erection of a large and magnificent church of stone in that place. It was destroyed by the Danes, and afterwards rebuilt by Gilbert de Goure, earl of Lincoln. Paulinus is also said, by historians, to have built the church at Southwell, in Nottinghamshire, which still exists, and in a good state of preservation; but evidently much of its architecture is of a later date than that of Paulinus. At the close of the seventh century, St. Chad, bishop of York, built a church at Barton-upon-Humber, where there is still standing an edifice of undoubtedly Saxon character. The successor of St. Chad was a man of somewhat different stamp, of the name of Wilfred. Active, persevering, and accomplished, he added considerably to the temporal dignity of the church, and was one of the greatest builders amongst the Saxon bishops. He was only thirty-five years of age when he entered upon his duties as bishop of York, and one of the first objects to which he gave his attention was the cathedral. He found the church built by Edwin and Oswald in a state of miserable neglect, the old roof dropping with rain-drops, and the windows open to the weather, and giving entrance to the birds, which made their nests inside the building. He repaired it substantially, "roofing it with lead," (being probably of thatch originally) "and prevented the entrance of birds and rain by putting glass into the windows, yet such glass as allowed the light to shine within." He also washed the walls of the old building, "and made them, as the prophet says, whiter than snow." St. Wilfred seems to have been the first to introduce the use of glazed windows into England, the light having been previously admitted into their buildings by openings covered with trellis-work, or with dressed skins of beasts, or sometimes with transparent horn or hair-curtains. Wilfrid had his glass from France; and Benedict Biscop, at a later period, is said to have brought from the same country artisans, to teach the English the method of its manufacture. Some reputed remains of this church at York, have been discovered beneath the present cathedral. At Ripon, Wilfrid built another church "of polished stone, with columns variously ornamented, and porches;" but his most famous work is the church at Hexham, which is described in glowing colours by Stephen Eddius, a cotemporary with Bede. He assures us that it had not a rival on this side of the Alps. Deep foundations, he says, were dug in the ground for the construction of subterraneous chapels, and passages of communication. On these foundations, walls were raised to a prodigious height, and were divided into three stages or stories, supported on square pillars and polished columns of different marbles. The capitals of the pillars and the arcades, and arch-walls of the sanctuary, were adorned with sculpture, paintings, and figures in relief, judiciously coloured; blue, green, and yellow, being the more predominant hues. The church was surrounded by galleries inside, and divided by inclosures and staircases, so that you might make the circuit of the building, without being seen from below. In the galleries above and below, were chapels dedicated to Our Lady and St. Michael, to apostles, martyrs, and confessors, all provided with the necessary ornaments.

"Richard, prior of Hexham, (Ricardus Hagust) who flourished about a century after the Conquest, when the original building was still in existence, though in a decaying state, has also left us a description of it, and both mentions the crypts and oratories, subterraneous, with winding passages to them, and relates that the walls were of immense length and height, supported on columns of squared, varied, well-polished stone, divided into three stories, adding, that the walls themselves, with the capitals of those columns by which the walls were supported, as also the coved ceiling of the sanctuary, Wilfrid decorated with histories, statues, and various figures projecting in sculpture from the stone, with the grateful variety of pictures, and with the wonderful beauty of colours. He also surrounded the very body of the church with lateral and subterraneous chapels on every side, which with wonderful and inexplicable artifice he separated by walls and spiral stairs above and below. In the very stairs, and upon them, he caused to be made of stone, ways of ascent, places of landing, and a variety of windings, some up, some down, yet so artificially, that innumerable multitudes of men might be there, and stand all about the very body of the church, yet not be visible to any that were below it."

Benedict Biscop was another builder, who erected the monasteries of Monk-Wearmouth and Jarrow; he seems to have brought masons and other artificers from France. He was a cotemporary with Wilfrid, and lived at the close of the seventh century. Adhelm, at a somewhat later period, was the founder of the abbey of Malmsbury, and two churches in the same town, one within the abbey and the other without, for the villagers or townspeople; he also built churches at Dorchester. The church of St. Peter at York, was rebuilt about the middle of the eighth century, in consequence of having suffered from fire in 741: it is described by Alcium in his poem *de Pontificibus et Sanctis Eccles.* Ebor.; who makes particular mention of its pillars, arches, vaulted roofs, windows, porticos, galleries, &c., which are the characteristics of a finished building. Under the article CATHEDRAL, will be found a curious description of the church at Ramsey, which, together with those already adduced, will, we think, afford some notion of the number of churches erected during the Saxon dynasty, or rather during that part of it when the Saxons had been converted to Christianity.

Acca, bishop of Hexham, was the builder of a noble church at that place, and is said to have adorned the side-walls with little tabernacles or shrines, arching over altars in honour of apostles and martyrs; at which the people often knelt in prayer, and on which were placed caskets, containing sacred relics. A new church erected at York in A.D. 780, by Albert, is said to have contained no fewer than thirty altars; it was several years in building, and was a very handsome structure, of lofty proportions, with an arched roof supported on massive columns and having several porches, which, with their different projections, caused an agreeable variety of light and shade when the sun shone upon them. This same bishop added considerably to the embellishments of the old church at York, which was built by king Edwin, and repaired by

Wilfrid; he erected a great altar or shrine over the place where Edwin had been baptized. This shrine was adorned with gold, silver, and precious stones, and above it was suspended by a chain from the roof, a large chandelier or *corona lucis*, with nine rows of lights, three in each row, to light it up by night. A large cross was raised at the back of this altar, of equally precious workmanship.

In Alfred's reign, Grimbald erected the ancient church of St. Peter at Oxford, and also the cathedral church at Winchester, at both which places, remains of his work are still supposed to exist. It is not improbable that some portions of Oxford cathedral are his work. It has been supposed that Grimbald was the first architect in this country who raised an arched roof, such as is to be seen at St. Peter's, Oxford, and at Winchester, in the crypts of those churches. But it is plain from Alcuin's account of the church built by him and Eanbald at York, one hundred years earlier, that that church had an arched roof.

The cathedral at Durham was erected by Aldham, A.D. 998, and here also, as at York and other places, a temporary church of timber was first erected, in which service was performed during the erection of the larger stone edifice. St. Dunstan was a great builder and restorer of churches and monasteries, and it is related, that during his episcopate, no less than forty monasteries were built or restored, amongst which may be mentioned the restoration of Ely, Peterborough, Tewkesbury, Malmesbury, Glastonbury, Evesham, Bath, and Abingdon; as also the foundation of the new abbeys of Ramsey, Hunts; Tavistock and Milton Abbas, Devon; and Cerne Abbas, Dorset.

Some idea of the number of churches erected during the Saxon period, will be formed, when we learn that, at the time of the Conquest, there were in Northamptonshire, where the forests were very extensive, and consequently but a small proportion of inhabitants, upwards of sixty village-churches, while the county-town contained eight or nine. In Derbyshire, there were not less than fifty, and five at least in the county-town, and these are exclusive of monasteries and the churches belonging to them; of which there were three or four in Northamptonshire, without reckoning Peterborough. In the town of Newark and the manor round it, including twelve or fourteen villages, were ten churches. In Lincolnshire, which was one of the most populous counties at this period, there were more than two hundred village-churches, without reckoning those of Lincoln and Stamford, or the monastic establishments.

Having established this fact, we have next to ascertain as to the character and appearance of such buildings, and also as to the material and method of construction. An opinion has been entertained by many, and still obtains amongst some persons, that the Saxon churches were very mean buildings, of a temporary character, and mostly constructed only of timber. To a certain extent this is true; many of their churches were certainly erected of timber, and were also mean in character when compared with those of a much later date; yet at the same time there can be no doubt, but that many, if not the majority, especially in the later part of the Saxon era, were constructed in a durable manner of stone, and were by no means so insignificant as some would have us to suppose. Many of the accounts left us by Saxon historians, and some of those above quoted, would lead us to form a much higher opinion of such structures; and although we must receive the panegyrics of these men not without some modification, considering that they spoke of things as beautiful only in a comparative sense, and that the standard of their comparison was fixed only by their own churches; still, we must not cast them aside as utterly groundless, or wilfully exaggerated. If we may believe, as there is good evidence for believing, that some remains of these old Saxon foundations still exist in the crypts of some of our larger churches, we shall be induced to give more credit to the Saxon accounts, than many persons are inclined to yield them. That churches were at this period constructed of masonry, we suppose few would question, after reading the above accounts; for in many instances the fact is especially mentioned, and in one or two instances such buildings are spoken of, and contrasted with those of timber, as at the cathedral at York, built by king Edwin, and that at Durham, erected at a considerably later period by Aldham, in both which cases, the stone structure is especially mentioned as being a substitute for the original or temporary building of timber. It may strike the reader as perhaps somewhat strange, that timber churches should still be constructed at so late a period, when the method of building in masonry had been known and practised for three centuries. A sufficient explanation of this apparent difficulty, is readily afforded in this particular instance, in the fact of the timber building being erected only for a temporary purpose, until the permanent edifice was ready for use. This inconsistency does, however, really exist in other cases, the one method of building did not cease, when the improved system had become established, but both were adopted in churches erected about the same period; both being equally intended for permanent use: the explanation is thus given:—

It is not indeed altogether to be wondered at, that in every age when society was thinly scattered over the face of the country, and the resources upon which ecclesiastical architecture depended, proceeded chiefly from the bounty of individuals, many churches not designed for a temporary purpose, would be constructed of materials so ordinary and so cheap; but we have other and more satisfactory reasons given by Saxon historians for this fact. These writers distinguish the two methods of building under the two terms *opus Scoticum*, and *opus Romanum*, the former referring to the more fragile structures, which were composed of split oak, and the latter to the more durable erections of stone.

Of this Scotch method, Bede says, "that Adrian, the first bishop of Lindisfarn, having departed this life, Finan, sent and ordained by the Scots, succeeded him in the bishopric, where he built a church in the isle of Lindisfarn, or Holy Island, since called the bishopric of Durham, after the manner of the Scots. This he made not of stone, but of hewed oak, and covered it with reeds; and the same was afterwards dedicated in honour of St. Peter, the apostle, by the venerable Bishop Meadows. Eadburh, the seventh bishop of that place, afterwards taking off the thatch, covered it with plates of lead, that is, both the roof and the walls."

It is probable, then, that the Saxons learned this method from their northern neighbours, against whom they had been brought over by the Britons, but with whom they had afterwards allied themselves, and by whose assistance they had been enabled to drive out the British, and establish themselves in their country. Whether the method had originally been brought from Ireland by the Scots, or whether it was a method common to both them and the Picts, is not certain; but it would seem, from an incident which we shall afterwards allude to, that a similar mode of building was employed by both people; or, at any rate, that the Picts were not acquainted with the method of building in stone.

These timber buildings were constructed of split or reft timbers, stood on their ends, and placed in close contact to each other. The ends were laid on an oak sill, and the heads framed together in a sort of lintel: of such simple construction were the walls; and the roof consisted, in all probability

of nothing more than reeds or thatch. A description of a church of this kind, which there is good evidence to believe is of Saxon date, is given under the article CHURCH: it is situated at Greenstead, near Ongar (the Saxon Aungre), in Essex. In this village, they have a tradition that the dead body of some king once rested here for a short time, and that the first edifice was a wooden chapel, erected for its reception. This is supposed to have been the body of St. Edmund, the king who was slain A. D. 946. In a manuscript, entitled *The Life and Passion of St. Edmund*, preserved in the library of Lambeth Palace, it is recorded, that, in the year 1010, and the thirteenth year of the reign of Ethelred, the body of St. Edmund was removed from Ailwin to London, on account of an invasion of the Danes, but that, at the end of three years, it was returned to Bedriceworth. And in another manuscript, cited by Dugdale in the Monasticon, and entitled "The Register of St. Edmund's Abbey," it is further added, "he was also sheltered near Aungre, where a wooden chapel remains as a memorial to this day." Now, the parish of Aungre, or Ongar, adjoins to that of Greenstead, where this church is situated, and the ancient road from London to Suffolk lay through it. It seems therefore not improbable, that this rough and unpolished fabric was first erected as a sort of shrine for the reception of the corpse of St. Edmund, which, in its return from London to Bedriceworth, or Bury St. Edmund's, as Lydgate, the monk of that abbey, says, was carried in a chest. Indeed, that the old oaken structure now called Greenstead church is this wooden chapel near Aungre, no doubt has ever been entertained; and the very style and character of the building would claim for it a Saxon antiquity.

The missionaries who had been accustomed to the buildings of Rome, introduced the manner of building churches among the Saxons more substantially, with stone, and in the Roman manner. Thus we find the king of the Picts—a people inhabiting the northern parts of Britain—soliciting Ceolfrid, a monastic abbot, to send him architects to build a church in his nation, after the Roman manner, promising to dedicate the same in honour of St. Peter, the prince of the apostles: and that he and all his people would always follow the custom of the holy Roman and Apostolic Church, as far forth as, being so remote from the Roman language and nation, they could learn the same. Here we also see the deficiency of the Picts, as well as that of the Anglo-Saxons, in the knowledge of sacred architecture, one building with wood, and the other with rough unhewn stones: and these, as well as the Irish churches, are covered with reeds and rushes, and the walls with skins. The windows, in some instances, were formed with lattice-of-wicker; in others, of horn and shells, oil-paper, &c.; and the rafts were of oak.

Buildings of this class, however, would seem to have been of very rude construction, the walls being composed either of coarse rubble-work, or of flints, piled up irregularly, and bound together by cement of some sort: such walls were, of course, obliged to be of great thickness. Sometimes we find Roman bricks worked up in the walls with other materials, but they are not laid in regular courses, as in the structures which had been erected by the Romans during their residence in Britain; they are found built up with the other materials, without regard to order or regularity. By this means, the buildings erected by the Romans in this island may be distinguished from the works of the Saxons; and it is curious that this test is similar to that applied to the buildings of Babylon; for it is there noted, that in the earlier buildings, the bricks indented with arrow-headed characters are always placed in a particular position with respect to the inscriptions

Whether, indeed, the method of building such stone erections was learned from the Roman missionaries, or originated in an imitation of the edifices which the Romans had left in the island, is by no means certain; we are inclined to think, however, that the latter is the more probable, for it would appear very unnatural that the Saxons should not have attempted to imitate the buildings which they found in the country even before Augustine made his appearance; although it is not unlikely that he and his companions might have given them further instructions, and imparted to them some knowledge of the method of building at Rome. This seems the more reasonable when we call to mind the letter which Gregory, bishop of Rome, sent by Melitus to Augustine, respecting the employment of existing buildings for places of Christian worship.

"When, therefore," says he, "Almighty God shall bring you to the most reverend man, our brother, Bishop Augustine, tell him what I have, upon mature deliberation on the affair of the English, thought of, viz., that the temples of the idols in that nation ought not to be destroyed: let holy water be made and sprinkled in the said temples; let altars be erected and relics placed; for if those temples are well built, it is requisite that they be converted from the worship of devils to the service of the true God, that the nation, not seeing those temples destroyed, may remove error from their hearts, and, knowing and adoring the true God, may the more familiarly resort to the same places they were wont."

From this it would appear, that the Saxons had erected temples for their worship before Augustine's appearance amongst them: and we hear, also, at a subsequent period, of Coifi, the heathen arch-priest in Northumbria, desecrating and destroying the idol's temple, upon his conversion to Christianity. That they had temples, therefore, there can be no doubt; the only question is, whether they built them themselves, or made use of such buildings as they found ready to their hands: the latter supposition is by no means improbable: whichever be the case, however, it is almost impossible, that, after a century's residence in the island, the Saxons should still remain totally unacquainted with the method of construction of those buildings which they had found there on their arrival.

"At the time the Saxons were converted," Mr. Bentham observes, "the art of constructing arches and vaultings, and of supporting stone edifices by columns, was well known among them; they had many instances of such kind of buildings before them in the churches and other public edifices erected in the time of the Romans. For notwithstanding the havoc that had been made of the Christian churches by the Picts and Scots, and by the Saxons themselves, some of them were then in being. Bede mentions two in the city of Canterbury; that dedicated to St. Martin, on the east side of the city, wherein queen Bertha performed her devotions, and which Augustine and his companions made use of at their first coming; and the other, that which the king, after his conversion, gave to Augustine, and which he repaired and dedicated to our blessed Saviour, and made it his archi-episcopal see. Besides these two ancient Roman churches, it is likely there were others of the same age in different parts of the kingdom, which were then repaired, and restored to their former use."

We do not suppose, however, that their acquaintance with the Roman method of building was very intimate, or that they had acquired much skill in the construction of vaults and arches, for their time was too much occupied with wars with the Britons, and quarrels amongst themselves, to admit of much opportunity for the cultivation of the arts of peace. All that we wish to assert is, that we were not entirely igno-

rant of Roman building, although practically, in all probability, not very expert in it, so that they would be ready to adopt some more easy method of construction, such as that afforded them by the Scots.

When at a later period the Anglo-Saxon Christians made a journey to Rome to visit the tombs of the Apostles, where churches were erected over them, and had seen those buildings, they blushed at the inferiority of their own low, dark, and gloomy fanes, and henceforth resolved to imitate what they had learnt to admire. Walls of wrought-stone, therefore, succeeded the rough material. After this we find that architects and work-people were frequently procured from abroad, to plan and raise ecclesiastical structures. The Anglo-Saxon churches, nevertheless, were of comparatively rude construction, until the time of Alfred the Great, when many, according to Asser, were rebuilt with stone, and, as far as can be ascertained, up to this time they were, with some few exceptions, of no great magnitude or dimensions, and almost entirely devoid of ornamental mouldings, though, in some instances, decorative sculpture and mouldings are to be met with. This improved method might be more properly termed the Roman manner, as being imported from Rome, and carried into execution by Roman and French workmen.

The general form of Saxon churches seems to have been that of a simple oblong or parallelogram, as we learn from Bede and other writers; some, however, were cruciform in plan, as that of St. Mary at Hexham, erected by St. Wilfrid, and which is described by Richard, prior of the same place, as being furnished with a "tower of a round form, from which four porticos or aisles proceeded." The church at Ramsay in Huntingdonshire, erected A. D. 969, was also of this form. This church also is said to have had two towers, one at the west end, and another in the centre of the transept, supported by four arches. Wolstan informs us that the old church at Winchester had a tower at the west end, but the new one at the east end of the church. Representations of buildings of this kind in some of the old Saxon illuminated books, tend to confirm this testimony. Dr. Milner observes that "The use of small bells (*nolæ*) in this country, if we may credit William of Malmsbury, may be traced as high as the fifth century. And it is clear from Bede, that even those of the larger kind (*campanæ*), such as sounded in the air, and called a numerous congregation to divine service, were employed in England as early as the year 680, being that in which the abbot Hilda died." Towers were also useful for other purposes, such as strongholds or places of refuge, to which the people might resort in cases of sudden incursion, to which they were especially liable from the Danes; also as beacons for travellers during the night, for we learn from Wolstan that the new tower at Winchester consisted of five stories, in each of which were four windows looking towards the cardinal points, which were illuminated every night. Such lights were most useful in those days, when the roads were few and bad, and the forests thick and numerous.

The few buildings which now remain, that can by written documents be proved to be of an age prior to the Conquest, have caused many writers to assert, that there is at present scarcely a true specimen of Anglo-Saxon architecture extant. This opinion has been very prevalent of late years; but we are strongly inclined to believe, that many more examples remain than is generally admitted. The causes by which the great scarcity of examples is accounted for by such writers, are principally these:—the necessary antiquity of the buildings; the furor of the middle-age architects for rebuilding churches in the latest styles; and the ravages of the Danes. Now we know from written testimony, as above shown, that a large number of churches were erected by the Saxons, and many of these built of stone in a durable manner. Will, therefore, the above causes be deemed sufficient to account for their total demolition? We think not. In the first place, then, as regards their antiquity, it may at the first blush appear unreasonable to expect to find many churches standing, after a lapse of twelve centuries; nor is it quite fair to cite such examples as those of Egypt, Greece, or Babylon, to refute this statement; for we are well aware, that they were constructed with much greater skill and strength than the Saxon churches. But there is no occasion to refer to such examples; we all admit that specimens of Norman architecture are still to be found without much difficulty, and in tolerable abundance; does it not, however, appear somewhat extraordinary, that we should have no lack of examples of structures built immediately after the Conquest, and yet scarcely any of the period just preceding that event; surely, it is not natural that the differences of numbers should be so very great; certainly, the difference of age will not account for it. This difficulty, which nullifies the first cause assigned for the paucity of examples, will equally affect the second. The third is somewhat more plausible, yet at the same time we cannot think that it accounts for such an extraordinary difference of numbers between Saxon and Norman remains as the advocates of this opinion would have us to believe; if so, the ravages of the Danes must have been of a more formidable description than we think history warrants us in believing.

But there are some positive reasons, which would lead us to conclude that a greater number of Saxon remains are now in existence, than is generally supposed. For instance, there are some churches in which Norman work is inserted into structures of a decidedly earlier, nay, much earlier date, which must in consequence belong to the period before the Conquest. The fact of work being anterior to the Conquest, is not, we are well aware, sufficient to prove it purely Saxon, for it is generally allowed as probable, that the Norman style was partially introduced into England before the invasion by William. In many of these instances, however, the older work is of a totally different character to the Norman, of a much more rude and barbarous description, and bears undoubted evidence of being of a date considerably antecedent to the Norman addition. In some cases, such remains are found in churches which are principally Norman, and this affords further proof of its antiquity; for it is reasonable to suppose, that a church partly re-edified in the Norman era must have been at that time a very old one.

An instance of the kind we allude to has recently come to light at Iver, Bucks, where it was discovered during restoration, that the north wall of the nave, which was apparently Norman, was in reality of earlier date, containing under the plaster the jambs of a door and window, as well as a string-course, both in the north and south walls, of an undoubtedly earlier epoch; a matter which was still further confirmed by the discovery of Roman bricks in the quoins of the east end of the nave-walls, thus proving that the shell of the building was of greater antiquity than its general appearance denoted.

On this subject, Mr. Freeman has introduced some very reasonable remarks, which we take the liberty of inserting:—

"I certainly think this," says he, "one of the strongest cases in favour of the existence, not only of buildings older than the Norman conquest, but of the existence of a distinct Anglo-Saxon style—two questions which ought never to be confused together in the way that they too often have been. To this subject I shall presently recur. In this Iver case, we have Norman work, and something older. There is no possibility of mistake; we have the marked familiar Norman

work of the twelfth century, introduced into an older building; no piece of architectural history can be more certain than that these arches are more recent than the wall in which they are inserted, and the window whose mutilation they have caused. There is no room for any question as to chronological sequence. The only possibility is, that they might be *late* Norman arches, cut through an early Norman wall. Mr. Scott, however, thinks that the 'northern piers and arches were probably erected about the year 1100.' With every deference to so eminent an authority, I should have placed them rather later, as the bases of the responds certainly seem to me too advanced for that date. But even putting the Norman work later in the century, we still have the fact, that the earlier work is not at all like early Norman, or Norman at all. There is this *a priori* objection to its being since 1066; while against its being of Anglo-Saxon date, there is nothing but the disinclination that exists in some minds to admit anything to be Anglo-Saxon. And though it would prove nothing against documentary evidence or strong architectural presumption, still, without such evidence or presumption, we should be shy of supposing such frequent reconstructions of such magnitude in an obscure village-church, as would be involved in the supposition that we have here two pure Norman dates; for though I should place the arches later than Mr. Scott does, they are certainly pure Norman, and not transitional, the case is briefly this: we have unmistakeable Norman work; we have also something else, at once earlier in date and different in character. The inference seems unavoidable.

"I observed above, that the questions of Saxon *date* and Saxon *style* are quite distinct. The real question is, whether the English, before the Conquest, possessed a national style distinct from Norman, in the same sense as other forms of Romanesque are distinct from it. In this sense, it does not prove a building to be Norman, to show that it was built after 1066; or to be Saxon, that it was built before Edward the Confessor. Certainly Harold himself not improbably built in the Norman style before that period; and, in obscure places, one cannot doubt but that Saxon churches were built for some time after. Even St. Alban's abbey is in many respects distinctly Saxon in character; and I am well pleased to find these facts taken up under this aspect in Mr. Parker's newly published 'Introduction to Gothic Architecture.' He there says, that 'the ordinary parish churches which required rebuilding (soon after the Conquest) must have been left to the Saxons themselves, and were probably built in the same manner as before, with such slight improvements as they might have learned in the Norman works.' He then goes on to mention—I presume from historical evidence—the Saxon churches of Lincoln as having been built after the Conquest, by the English inhabitants, dispossessed of their dwellings in the upper city by William and Bishop Remigius. No fact could be more acceptable to the believers in a distinct Saxon style, if the Englishmen of Lincoln continued—even when the Norman cathedral was rising immediately over their heads—to build in a manner, not differing merely as ruder work from more finished, but having essentially distinct characters of its own: the inference is irresistible, that this was but the continuation of a distinct style, which, in those larger edifices, which have been almost wholly lost to us, would probably present distinctive features still more indisputable. The mere chronological proof of any existing building being older than the Conquest, would never have half the same value as such a testimony as this, which represents Saxon and Norman architecture co-existing in antagonistic juxtaposition. The fact is, however, only the same as we find occurring, to a greater or less extent, at every change of style. At all such transitional periods, we find not only every intermediate style, but the simultaneous use of the two styles, each in a state of tolerable purity. And the circumstances which attended the change from Saxon to Norman architecture, would naturally tend to make this phenomenon more conspicuous than in subsequent transitions. This change was no native development; it was the innovation not only of foreigners, but of conquerors and oppressors; and, whilst national honour might require, the circumstances of the time would compel, the rude and obscure structures which still continued to be raised by Englishmen, to adhere in all respects to the native precedents of better times. Wealth, art, ecclesiastical influence, and munificence were all enlisted on the side of their tyrants."

The tower of Earls-Barton church in Northamptonshire, as well as that of Barton-upon-Humber in Lincolnshire, bear marks of great antiquity, and are ascribed by Mr. Britton to the Anglo-Saxons. Both are evidently much older than the church to which they belong, which are good specimens of the Norman style. Nothing, Mr. Britton observes, can be found more resembling the towers now under notice, than the architectural drawings in certain manuscripts of acknowledged Saxon origin. In the British Museum, and in the Gregorian Gospels preserved in the library of Salisbury Cathedral, are drawings by Anglo-Saxon scribes, in which the triangular arch and columns, resembling balusters with two or three bands, are represented, and seem to be rude delineations of architectural members, very similar to those in the towers of the two Bartons and Barneck, in Northamptonshire, in which they are employed.

In some churches where work—supposed to be Saxon—exists, are to be seen Saxon and Latin dedicatory inscriptions, in which the founders, and others connected with the church, are alluded to, and by this means we are enabled to form some certain judgment as to their date.

"In the church of Kirkdale, in Rydale, in the North Riding of Yorkshire, over the south door, is a curious inscription in Saxon characters, of which a plate is given in the fifth volume of 'Archæologia.' The inscription is accompanied by an ancient dial, and is placed over a doorway with a plain semicircular arch. It is engraved on one entire freestone, 7 feet 5 inches long, and 1 foot 10 inches high, and is in perfect preservation, except a small part in the centre, where the inscription is disfigured, but not obliterated, by the weather. This seems in some measure to be owing to its being defended by the porch, which entirely covers it, except by two angles, and consequently must have been of later erection; which is further improved by its having been formerly plastered over with lime, or some other cement, as appears by the remains of it in the interstices of the letters, and in the vacancy where the hand of the dial has been broken off. The inscription may be read thus: Orm. Gamal. Suna. Bohte. Sanctus. Gregorius. Minster. Thonne, Hit. West. æl. To. Brocan. And. To. Falan. Chehitle. And. Man. Newan. From. Grunde. Christe. And. Sanctus. Gregorius. In. Eadward. Dagum. Cng. In. Tosti. Dagum. Earl. "Orm, Gamal's son bought St. Gregory's church then it was all fallen down. and gone to ruin. Chehitle and others renewed it from the ground to Christ and St. Gregory, in Eadward's days, the king, and in Tosti's days, the Earl;" and under the dial. And. Hawarth Me. Wroht. And. Brand. Prs. "and Hawarth me made and Brand the priest."

"Tosti, who was fourth son of Godwin, earl of Kent, and brother to king Harold, was made earl of Northumberland, by Edward the Confessor, in 1056, on the death of earl Leward. This earl was driven from his earldom by his oppression, and was killed at Stamford bridge, near York, in 1066.

The inscription must therefore be dated between those years. From Doomsday book it appears that Orm was the owner of Kirkdale and the districts adjacent, in Edward the Confessor's time; and from Simeon of Durham we learn, that a certain thane in Yorkshire, by name Orm, the son of Gamal, married Ethelrith, one of the five daughters of Aldred, earl of Northumberland," &c.

"On one of the walls of the church of Aldborough in Yorkshire, is the following Saxon inscription:—'Ulf hit araeran cyrice for Hanum and for Gunthard saula;' *i. e.*, Ulf commanded this church to be erected for the souls of Hanum and Gunthard." From many circumstances, this church is evidently the original Anglo-Saxon structure, with a few modern additions, as pointed windows, &c. The walls in general are made of round pebble-stones, supposed to have been gathered from the sea-shore in the neighbourhood, which kind of stones, by a strong cement, made very durable buildings; but the lower part of the south wall of the chancel is built with hewn stone, such as was generally used in our most ancient cathedral churches, upon which there are some grotesque figures; and in the north wall is a narrow window, about 5 feet high; the chancel door also, which is a south entrance, is low and narrow, and has over it an elliptic arch, ornamented with zig-zag work. Ulf, who is mentioned in the inscription as its founder, was lord of the whole of this part of the Saxon province of Deira, or the country bounded by the Humber and the Tees, about the time of Canute."

Another inscription-stone was dug up at Deerhurst, and is now amongst the Arundelian marbles at Oxford: it commemorates the construction of a church there by earl Odda, who died A. D. 1056. The most ancient inscription, however, is probably that at Jarrow, which is apparently of the same date as the erection of the church, A. D. 684.

Our object in bringing these examples forward, is not so much to prove each example of Saxon origin, but rather to establish the date of a particular class of work; for if in one or two cases this be indubitably proved to be Saxon, we have every right to conclude that the same kind of work is of the same origin wherever it may be found. It somewhat corroborates our position, that many churches in which such work has been discovered have been alluded to by the Saxon historians. Thus a probable inference may be deduced from the ancient chronicles of the monastery of Dover, that the old church near the castle was founded by Eadbald, king of Kent. The churches of Jarrow and Monk-Wearmouth, in which supposed Saxon work exists, are both mentioned as having been founded by Benedict Biscopius, A. D. 681: so also of the churches of Ripon and Hexham.

That the church at Brixworth, in Northamptonshire—which is one of the most perfect specimens of this kind of building—is of an age anterior to the Conquest, we have many proofs. Mr. Britton judges it to be a building of the time when the Romans were in possession of the island, after the Britons were converted. It is evident, from Doomsday book, that it was in existence at that time; and in Leland's Collectanea we may trace it to the time of Cuthbald, the second abbot of Medeshamsted, afterwards called Peterborough, who was contemporary with Wulphere, king of Mercia, who died in 670. The building is almost entirely formed of Roman bricks; it has, at its western end, in addition to the square tower, a round one, containing a newell staircase. In its original form, it appears to have consisted of a spacious nave and narrow aisles, a large chancel, and a western tower, with a clerestory to the nave, and the chancel divided from it by a large arch. The construction of this church is particularly curious, the walls being mostly built with rough red-stone rag, in pieces not much larger than common bricks; and all the arches turned, and most of them covered with courses of bricks, or tiles, as they may be called. The original doors and windows have all round arches; but many additions have been made in more recent ages.

Further proof in favour of such work belonging to the Saxon age, is to be observed in the similarity which exists between the details of such buildings and those found in the illuminated Saxon manuscripts, where representations of buildings are introduced. In the illuminations in the paraphrase of Cædmon, of which the date is supposed to be about A. D. 1000, are various representations of architectural details; and amongst these are specimens of *long and short* work, semicircular and triangular arches, graduated imposts or capitals, low pyramidal roofs to towers, and the well-known baluster-shafts.

Putting all this evidence together, we think there can remain little doubt but that the particular style in which many of our existing churches, or portions of churches, have been erected, is nothing else than decided Saxon.

It is now time that we give some description of the architectural peculiarities of this style; such description will be necessarily short and imperfect, on account of the comparative paucity of the remains, and the uncertainty respecting them. The general character is extreme rudeness of construction, and almost total absence of ornament; the workmanship, at the same time, being rough and unfinished.

The masonry consists of rubble or rag-stone, rudely piled together, and often rendered on the exterior with a coating of plaster. The angles are bonded together with quoins of ashlar-work, arranged in a peculiar manner, and termed *long and short* work. They are composed of stones of two different lengths, placed alternately one above another—first a short one, then a long one, and so on; or, in other words, of stones laid alternately flat and upright on the edge, the flat ones exceeding in horizontal dimensions, the upright in vertical; the latter, however, are usually of greater dimensions in the height than the former in width. We frequently find, also, projecting a little from the general face of the masonry, narrow square-edged strips of ashlar, carried up vertically from bottom to top of the walls, and consisting generally of long and short pieces of stone placed alternately. Not unfrequently strips of stone of a precisely similar character were carried horizontally along the walls, after the manner of a string-course, especially in towers, where they are employed to divide the height into different stories; they also serve for the upright strips to terminate against both at top and bottom. The vertical strips bear some resemblance to pilasters. By some persons this arrangement is said to be in imitation of timber-construction; but, for our own part, we think it bears a much closer likeness to the pilaster strip-work so common in the Lombardic structures of the continent. So remarkable, indeed, is this resemblance, that we consider it almost sufficient evidence of itself, to prove that such buildings have been erected in imitation of the continental ones. *See* LOMBARDIC ARCHITECTURE. In many cases, the walls are so covered with this strip-work as to be divided by them into a number of panels. Sometimes, as in the tower of Earls-Barton church, we have them arranged after a kind of ornamental design, in diamonds, semicircles, &c. Occasionally, in all probability, work of this kind is hidden from view by the rendering of plaster on the walls.

Roman bricks are frequently found worked up in walls of Saxon masonry, but, as we have said before, without any regularity or arrangement. Herring-bone masonry, which consists of stones or bricks laid at opposite inclinations in

alternate courses, is also to be found in Saxon-work; but it is not peculiar to it, being also found in both Roman and Norman walls.

The arches in this style were either semicircular or triangular, if the latter can be properly styled arches, which consist merely of two long stones resting on imposts, and inclined towards each other till they meet, and abut against each other at the apex. The semicircular form is, however, by far the more common of the two; it is usually quite plain, having only a single soffit, without any recess or sub-arch: not unfrequently arches of this kind receive somewhat of a finish by the addition of a hood-mould, composed of square-edged strip-work, projecting a few inches from the surface of the wall: it follows the shape of the arch, and is either terminated by the impost, or continued down to the ground. Occasionally we find arches recessed, or having a sub-arch, as at Bishophill, York; but this is probably of late date, although truly Saxon, as is evident from the square-edged strip forming a hood-mould, as just described: rarely, also, the arch is enriched with bold roll-mouldings on the face or soffit, or on both, as at Wittering church, Northamptonshire; and these are sometimes continued down the impost to the ground.

The imposts on which the arches rest are usually nothing more than square-edged projecting blocks of stone, having sometimes the lower arris chamfered; occasionally they are moulded, the mouldings consisting chiefly of fillets or plat-bands varied with bold semi-cylindrical or roll-mouldings; and sometimes they are enriched with rude attempts at sculpture. The piers are mostly square, plain, and with no more capital than is formed by the impost.

The doorways are constructed with both kinds of arches; the semicircular being most prevalent, and in some of the more ancient examples, the archivolt is composed of Roman bricks; they are mostly, however, of stone, of the description given above, being frequently provided with the projecting hood-mould, which is sometimes stopped on the impost, or a horizontal string-course of strip-work, and at others continued to the ground. The imposts or abaci are of the same description as above, and the jambs are either composed of the usual long and short work, with the horizontal stone bonding into the wall, or of two long blocks placed upright on their ends with a shorter one between them, which is, however, no wider than the long ones. Triangular-headed doorways are of similar general description to the semicircular; there is an example in Brigstock church.

The windows are generally of a very rude description; those in the body of the church, consisting principally of single lights of small size, and having semicircular heads; they present a marked difference from the Norman windows to the same kind, in being splayed from the middle of the thickness of the wall both ways, that is to say equally both towards the interior and exterior of the building; whereas the Norman windows splay from the exterior only in one direction, the glazing being inserted near the external surface of the wall. Small windows are sometimes seen with square heads, of a rude oblong form.

The windows, which deserve the greatest attention, and which form a characteristic of the style, are those found in the upper stages of Saxon towers. They generally consist of two semicircular-headed lights, divided by a rude shaft of peculiar description, and termed *baluster-shafts*, from their appearance, which is that of a baluster with a bold capital and base, both of which are usually composed of cylindrical or roll-mouldings, and the former surmounted with a heavy abacus. This abacus runs nearly through the thickness of the wall, and from it the arch springs, being supported on the other side by an impost of similar description worked up in the wall. The baluster-shaft frequently swells out in the middle of its height, and is sometimes divided in the middle by a band of roll-mouldings, swelling out above and below midway between the band and capital and the band and base; it is often plainly cylindrical, without bands or other interruption. At Monk-Wearmouth, the shaft swells in the centre, but has neither capital nor base. Sometimes, such windows of two lights are coupled together by a semicircular hood of strip-work extending over both, and carried down vertically to the bottom of the lights. In the topmost story of the tower of Earls-Barton church, there is a window of the above description, divided by baluster-shafts into six lights. Triangular-headed lights are found in this and other situations.

Respecting Saxon vaulting, the following account of that in the crypt of Repton church, is given by Mr. Bloxam, in his valuable manual:—"The crypt beneath the chancel of Repton church, Derbyshire, is, perhaps, the most perfect specimen existing of a crypt in the Anglo-Saxon style; and of a stone-vaulted roof sustained by four piers of singular character, slender and cylindrical, with a spiral band or moulding round each, and the entasis exhibiting that peculiar swell we find on the baluster-shafts of Anglo-Saxon belfry windows; the vaulting, which is without diagonal groins, bears a greater similarity to Roman than to Norman vaulting; and the crypt was entered through the church, by means of two winding passages."

Amongst the more noted churches in which Saxon remains are supposed to exist, we may mention the following:—Barton-upon-Humber, Lincolnshire; St. Benedict's, Cambridge; Brigstock, Northamptonshire; Brixworth, in the same county; Bosham, Sussex; Clee, Lincolnshire; church near Dover-Castle; Earls-Barton, Northamptonshire; Deerhurst, Gloucestershire; Hexham, Durham; Jarrow, in the same county; Kingsbury, Middlesex; Lavendon, Bedfordshire; St. Michael's, St. Alban's, Herts; Monk-Wearmouth, Durham; Repton, Derbyshire; Sompting, Essex; Tintagel, Cornwall; Wing, Bucks; Worth, Sussex; St. Mary, jun., Bishophill, York.

For further information on this subject, we refer the reader to Cathedral, Church, and other articles of a similar character.

SCABELLUM, (Latin,) in ancient architecture, a kind of pedestal, usually square, sometimes polygonal, and very slender and high, commonly ending in a sort of sheath, or scabbard, or profile, in the manner of a baluster. It was used to support bustos, or relievos.

SCAFFOLD, (from the French, *eschafaut*, or Dutch, *schavot*,) an assemblage of planks, or boards, sustained by tressels, or pieces of wood fixed in the wall, upon which masons, bricklayers, &c., stand, whilst carrying up a wall; or used by plasterers, &c., when plastering the ceiling.

The different members of a scaffold are termed standards, ledgers, and putlogs. The standards are upright poles of fir of considerable length, and about 6 inches in diameter, fixed firmly in the ground; the ledgers are horizontal poles lashed to the standards, and running parallel to the work to be erected, and the putlogs are transverse pieces about 6 feet in length, laid horizontally from the ledgers to the walls, on which the scaffold-boards are placed.

Of late years, a much improved method of building scaffolds has been employed, especially on large works; they are more regular in their construction than the old method, being composed of a series of trussed frames, consisting of a number of vertical and horizontal timbers braced together diagonally; they have the advantage of being erected independent of the building itself. At the top of such scaffolds is frequently a

carriage running on a rail in a longitudinal direction; and this carries a windlass, which moves across it in a transverse direction, and therefore can be brought to act at any point which may be desirable.

SCAGLIOLA, an imitation of the most beautiful marbles, such as sienna, jasper, brocatello, and porphyry: it is hard, and, when finished, bears a very fine polish. For the method of preparing it, *See* PLASTERING.

SCALE, (from the Saxon,) a line divided into a certain number of equal parts, each of which is subdivided into others, in order to express the parts of an object of a different size, either in a drawing or in a model, but in the same proportion as the original.

SCALE, a mathematical instrument, consisting of one or more lines drawn on wood, metal, or other matter, divided into equal or unequal parts, of great use in laying down distances in proportion, or in measuring distances already laid down. There are scales of several kinds, accommodated to the several uses; the principal are, the *plane scale*, the *diagonal scale*, *Gunter's scale*, and the *plotting scale*. *See* INSTRUMENTS, and PLOTTING SCALE.

SCALENE TRIANGLE, (from the Greek, *σκαληνος*, *oblique*, or *unequal*,) a triangle that has no two equal sides, nor any of its angles a right angle. A cylinder, or cone, whose axis is inclined to its base, is likewise said to be *scaleneous*.

SCAMILLI IMPARES, a term of uncertain meaning, used by Vitruvius, and much contended about among the critics, though, in effect, it signifies no more than certain zoccoes, or blocks, serving to raise the rest of the members of an order, column, statue, or the like, and to prevent their being lost to the eye, which may chance to be placed below the level, or below the projecture of some of the ornaments. The scamilli are well enough represented by the pedestals of statues. *See* PEDESTAL.

SCAMOZZI, VINCENZO, a celebrated architect, born at Vicenza in 1552. He was educated under his father, Gian-Domenico, an able artist in the same branch; and, at the age of seventeen, he made designs for buildings that were very highly esteemed. He went to Venice for improvement, where Palladio and others were then employed about works of magnitude and consideration, and he made very rapid advances in his profession. At the age of twenty-two, he composed a treatise, in six books, *De Teatri e delle Scene*, which has never been published. In a visit to Rome, he was engaged in the diligent study of the remains of antiquity to be found in that city, and in the study of mathematics under the celebrated Clavio. After extending his tour to Naples, he returned, in 1583, to his native city, and settled at Venice, where, Palladio being dead, he became the first architect, and was employed in various public and private works, of which one of the most remarkable was the additions to the library of St. Mark. He was sent for to Vicenza to finish the famous Olympic theatre, by which he gained credit. In 1588, Duke Vespasian Gonzaga engaged him in the construction of a new theatre at his town of Sabioneta. After this, he visited many of the chief places on the continent; and decorated several other cities in Italy, besides Venice and Vicenza, and few artists seem to have enjoyed a more extensive reputation. In 1615, he published a work, entitled *L'Idea dell'Architettura Universale*, in six books, which contains many useful observations and instructions. The sixth book, which contains the five orders of architecture, is most esteemed, and has been translated into the French language. Scamozzi died in 1616. Besides the writings above-mentioned, he published a work of descriptions, of which three chapters contained the buildings and topography of Rome.

SCANDULÆ, in ancient house-building, shingles, or flat pieces of wood, used by the Romans instead of tiles, to cover houses. This, according to Cornelius Nepos, was the only covering used in Rome till the war with Pyrrhus, 470th year of the city.

SCANDULARII, among the Romans, mechanics who prepared the scandulæ used in covering houses, who were exempted from all public services.

SCANTLING, (from the French, *eschantillon*,) the transverse dimensions of a piece of timber in breadth and thickness.

SCANTLING is also the name of a piece of timber; as of quartering for a partition, or the rafter, purlin, or pole-plate of a roof.

All quartering, under five inches square, is termed *scantling*.

In all scantlings for shoaring, the master-carpenter charges one-third for use and waste; though, when used in very considerable quantities, and in large scantlings, one-fourth is deemed sufficient.

SCANTLING, in masonry, the size of the stones in length, breadth, and thickness.

SCAPE, (from the Latin, *scapus*, a stalk, or stem) the fust or shaft of a column. It is also used for the little hollow, above or below, which connects the shaft of a column with its base, or the part where it appears to rise out of the base.

SCAPPLE, to reduce a stone to a plane surface, without working it smooth.

SCARFING, a term used to denote the junction of two pieces of timber, by being bolted or nailed transversely together, so that the two appear but as one. The joint is denominated a *scarf*, and the timbers are said to be *scarfed*.

In scarfing a beam, the joint or seam must have its dividing surface or surfaces perpendicular to one side of the beam, so as to resist a strain in the direction of the fibres. *See* CARPENTRY.

SCENOGRAPHY, (from *σκηνη*, *a scene*, and *γραφω*, *to describe*,) the method of representing solids in perspective; the ichnography is the ground-plan; the elevation, a representation of the vertical planes upon a vertical plane given in position; and when the whole is represented at one view, the representation is called *the scenography*.

SCENOGRAPHY OF A PYRAMID, the same as its perspective representation.

SCHEME, (from the Greek, *σχῆμα*,) the representation of any design, or geometrical figure, by lines, so as to render it clear to the understanding.

SCHEME ARCH, or SKENE ARCH, a circular arch, whose dimensions are not greater than a semicircle. *See* ARCH.

SCHOFEET. *See* SOFFIT.

SCHOLIUM, (from *σχολιον*) a note, annotation, or remark, occasionally made on some passage, proposition, or the like. The term is much used in geometry, and other parts of mathematics; where, after demonstrating a proposition, it is frequent to point out how it might be done some other way; or to give some advice or precaution, in order to prevent mistakes; or add some particular use or application thereof. Wolfius has given abundance of curious and useful arts and methods, and a good part of the modern philosophy, the description of mathematical instruments, &c., all by way of scholia to the respective propositions, in his *Elementa Matheseos*.

SCIAGRAPHY, or SCIOGRAPHY, (from *σκια*, *a shadow*, and *γραφω*, *to describe*,) the draught of a building, cut in its length and breadth, to display the interior: in other words, the profile, or section of it.

SCIMA. *See* SIMA.

SCOLLOPED MOULDING, a moulding commonly found in Norman buildings, of which the title is sufficiently descriptive.

SCOPAS, an eminent Grecian artist, of the isle of Paros, who flourished in the year before Christ 430. He was equally distinguished as a statuary and sculptor, and was the author of many works which placed his name on a level with those of Phidias and Praxiteles. One of the columns in the temple of Ephesus was his performance; as was one of the four sides of the famous tomb of Mausoleus. Rome possessed several fine works, the productions of Scopas; among which, the most admired were the great group of Neptune and other marine deities, in the Flaminian circus; which, of themselves, might, according to Pliny, have been the labour of a whole life. The same writer speaks of a Venus, the work of Scopas, surpassing that of Praxiteles.

SCOTIA, (from *σκοτος*, *obscurity* or *darkness*,) a recessed moulding, of an elliptical or circular section, placed between the tori, in the bases of columns. The scotia is most frequently formed by the junction of circular areas of two different radii; but this is upon an erroneous principle, as it ought rather to be a regular portion of an ellipsis. *See* MOULDINGS.

The scotia has an effect just opposite to that of the quarter-round. The workmen frequently call it *the casement;* and, from its form, it is sometimes termed *the trochilus*. According to Felibien, the cavetto is a fourth part of the scotia.

In the Ionic and Corinthian bases, there are two scotias, the upper of which is the smallest.

SCRATCH WORK, (from the Italian, *sgraffiata*,) a mode of painting in fresco, by preparing a black ground, on which is laid a white plaster; which white being taken off with an iron bodkin, the black appears through the holes, and serves for shadows. This kind of work is lasting; but being very rough, it is unpleasant to the sight. It is chiefly used to embellish the fronts of palaces, and other magnificent buildings.

SCREEN, a partition, or means of separating one part of an edifice from another. Screens are very frequent in churches, especially in those of a more important character, where they are used to partition off chantry-chapels, and such like, from the main building; to enclose the choir, and to separate the chancel from the nave, &c. Such screens are of various materials, but usually of wood or stone, and many of them are of excellent designs and workmanship. *See* ROOD-SCREEN.

The term is also applied to any means of shelter or protection against heat, cold, light, &c.

SCREEN, (from the French, *escran*,) an implement used in making mortar, consisting of three wooden ledges joined to a rectangular frame at the bottom; the upper part of which frame is filled with reticulated wirework, for sifting sand or lime.

SCREW, (from the Dutch, *scroeve*,) one of the six mechanical powers; chiefly used in pressing or squeezing bodies close, though sometimes also in raising weights.

The screw is a spiral thread, or grove, cut round a cylinder, and everywhere making the same angel with the length of it. So that, if the surface of the cylinder, with this spiral thread upon it, were unfolded and stretched into a plane, the spiral thread would form the section of an inclined plane, whose length would be to its height, as the circumference of the cylinder is to the distance between two threads of the screw; as is evident by considering, that in making one round, the spiral rises along the cylinder the distance between the two threads.

Hence the threads of a screw may be traced upon the smooth surface of a cylinder thus: cut a sheet of paper into the form of a right-angled triangle, having its base to its height in the above proportion, viz., as the circumference of the cylinder of the screw is to the intended distance betweer two threads; then wrap this paper triangle about the cylinder, and the hypothenuse of it will trace out the line of the spiral thread.

When the spiral thread is upon the outside of a cylinder the screw is said to be a *male* one; but if the thread be cut along the inner surface of a hollow cylinder, or a round perforation, it is said to be *female;* and this latter is also sometimes called the *box* or *nut*.

When motion is to be given, the male and female screw are necessarily conjoined; that is, whenever the screw is to be used as a simple engine, or mechanical power. But when joined with an axis in peritrochio, there is no occasion for a female; but in that case it becomes part of a compound engine.

The screw cannot properly be called a simple machine, because it is never used without the application of a lever, or winch, to assist in turning it. The force of a power applied to turn a screw round, is to the force with which it presses upwards or downwards, setting aside the friction, as the distance between two threads is to the circumference where the power is applied.

For the screw being only an inclined plane, or half wedge, whose height is the distance between two threads, and its base the said circumference; and the force, in horizontal direction, being to that in the vertical one as the lines perpendicular to them, viz., as the height of the plane or distance of the two threads, is to the base of the plane, or circumference, at the place where the power is applied; therefore the power is to the pressure, as the distance of two threads is to that circumference.

Hence, when the screw is put in motion; then the power is to the weight which would keep it in equilibrio, as the velocity of the latter is to that of the former. And hence their two momenta are equal, which are produced by multiplying each weight, or power, by its own velocity.

SCRIBING, a term applied to the edge of a board, when fitted upon any surface.

Thus the skirting of a room is scribed to the floor, in the most ordinary cases; and the method of doing it is as follows:—Lay the edge of the intended skirting upon the floor; then take a pair of compasses, and extend the points so as to be equal to the greatest breadth of the hollow between the floor and the skirting-board, taken in a vertical direction; begin at one end of the board, and, with one point upon the floor, and the other upon the wood, and both points in a line perpendicular to the horizon, draw the compass towards the other end, keeping both points always in a straight line, parallel to the floor, and in the surface of the board, or in the surface of the board extended; and the upper point will trade a line on the board, exactly similar to the surface of the floor; so that, if the superfluous part below the line be cut away, the board will fit close to the floor.

SCRIBING, in joinery, the act of fitting one piece of wood upon another, so that the fibres of both may be perpendicular to each other, and the end cut away across the fibres, so as to fit upon the side of the other.

This method is useful in doors and sashes, when it can be done; but in quirked mouldings, recourse must be had to mitering.

SCROLL, see VOLUTE.

SCULPTURE, (from the Latin *sculptura*,) the art of carving in wood, stone, &c. The term is also used for the carved work itself.

SCUTCHEON, an heraldic shield.

SCYRIUM MARMOR, a name given by the ancients, sometimes to a white, and sometimes to a yellowish marble; both used in the public buildings of the Romans, but seldom in statuary, not being capable of a high polish.

SEALING, the fixing of a piece of wood or iron on a wall with plaster, mortar, cement, lead, or other binding, for staples, hinges, or joints.

SEASONING TIMBER, the act of preparing it for building, by expelling the natural sap.

Added to the other defects of modern English building, particularly that of the metropolis and its immediate neighbourhood, is the improper state in which timber is used.

The major part of our best timber is imported from the north of Europe, *and is immersed in docks*, and lies there floating till it is sold for immediate use; the consequence of this is, that the timber (though even it may be previously seasoned) becomes swelled to much beyond its former and its ultimate bulk; is hastily framed together while the very water is running from it; and very soon after it is so converted, it shrinks to such a degree, that every tenon becomes loose, every joint strains falsely from the shrinkage, and every ceiling and quartered partition cracks by the opening, diminishing, and distortion of the wood.

Some persons fancy, that to immerse timber in water seasons it; however this may be, (and it may well be doubted,) it does not render it fit for use, but the very reverse of it. Timber for ordinary purposes should be shrunken to its smallest limits before it is worked up; the least possible change should occur in the timber after the work is framed and adapted; for all the oblique joints of it, by shrinkage, become perfect, each bearing-timber then hangs straining upon a single point, instead of upon a flat direct abutment; thence many of the struts and other bearing-timbers rend by the weight, hanging merely upon their angles.

In very many cases, dry-rot is engendered in our hastily-constructed buildings, by the quantity of dock-water pent up in the timber, by its mortises and other joints, by the plastering, by the brickwork, and by many other causes. While our timber is at the saw-pit, the water not unfrequently streams from it, and though it may appear choice and close when first selected and wrought, the sun and air in a very few days suffice to render it coarse, open, full of cracks, and wholly unfit for good work.

Our specifications are very strict in the requirement of the perfection and proper seasoning of timber, but these precautions are almost useless. The builder can hardly procure, at any price, timber which is not in a dropsical condition; and twelve months, in general, are sufficient to diminish in bulk, and to split our carpentry, alike whether it be framed for the palace or the cottage—for the public or the individual.

After timber is felled, it should be piled up perpendicularly in an airy dry place, with proper interstices to admit a free circulation of air; and thus both rain and the excessive heat of the sun being excluded, the timber will dry without shakes or fissures.

Some persons, however, prefer to keep the timber as moist as they can, by immersing it in water, to prevent its cleaving. In this case, when the boards have laid a fortnight under water, they have them set upright in an airy place during the heat of summer, and turned every day; by this practice, new-sawn boards, it is said by those who are the advocates for the soaking-system, will floor much better than those which have had many years dry-seasoning.

We are, as we have said, opposed to this practice; but to prevent all possible accidents, when floors are laid, let the edges be shot and brought to a joint, or nearly so; lay them down the first year, and finally fasten them the next, they will then remain without shrinking, provided they be kept dry.

The following particulars should be attended to in seasoning wood. The sudden decay of the timber is generally owing to the sappy nature of the exterior surface, which is by no means capable of being remedied by any application of paint previous to its being seasoned; on the contrary, it has been proved, that such application is actually injurious, since it hinders the free admission of air and heat, which would have the property of extracting that sappy quality which so much contributes to decay and rottenness. When this practice is adopted, the sap strikes inwardly, and, making its way to the heart of the wood, the substance is presently contaminated and destroyed.

As a means of preventing this evil, the timber is sometimes scorched over a flame, turning it about till every side acquires a sort of crusty surface; in doing this, it necessarily follows, that the external moisture is dissipated. After this process, a mixture of pitch and tar, sprinkled with sand and powdered shells, may be advantageously applied to the parts intended to be under water, while those more in sight, after being well scorched, and while the wood is hot, should be rubbed over with linseed-oil mixed with a little tar. This will strike deeply into the grain of the wood, and will soon harden so as to receive as many coats of paint as may appear necessary.

It has been found, that fir-timber, thus prepared is nearly equal to oak for durability.

The following valuable observations on the seasoning of timber are extracted from an able article on "Timber—Its Treatment and Uses," by Mr. James Wylson, published in the Second Volume of the "Builder:"—

"There are natural and artificial means of seasoning, both of which have their recommendations; but the former has certainly the right of preference, as it gives greater toughness, elasticity, and durability, and therefore should always be employed in preparing timber for carpentry.

"When there is time for drying it gradually, all that is necessary to be done, on removing it from the damp ground of the forest, is to place it in a dry yard, sheltered from the sun and wind, and where there is no vegetation; and set it on bearers of iron or brick in such a manner as to admit a circulation of air all round and under it. In this situation it should continue two years, if intended for carpentry, and double that time if for joinery, the loss of weight, which should take place to render it fit for the purposes of the former, being about one-fifth, and for the latter about one-third. If it is to be used round, it is good to bore out the core, as by so doing, the drying is advanced, and splitting prevented, with almost no sacrifice of strength. If it is to be squared into logs, it should be done soon after some slow drying, and whole-squared if large enough; as that removes much of the sap-wood, and facilitates the drying, and prevents the splitting, which is apt to take place when it is in the round form, in consequence of the sap-wood drying before the heart, from being less dense; also, if it may be quartered, it is well to treat it so after some time, as the seasoning is by that means rendered more equal. It is well also to turn it now and then, as the evaporation is greatest from the upper side.

"To prevent timber warping, it should be well seasoned before it is cut into scantlings, and the scantlings should be cut some time before they are to be used, in order that the seasoning may be as perfect as possible; and if they can be set upright, so much the better, as then they will dry more rapidly, and, as the upper dries sooner than the lower side, they ought therefore to be reversed at intervals.

"When there is not time for actual drying, the best method that can be adopted, especially for sappy timber, and if strength is not principally required, is immediately, on felling, to immerse it in running water, and, after allowing it to remain there about a fortnight, to set it in the wind to dry. This renders timber less apt to crack and warp in drying, and less subject to be worm-eaten, especially the more tender woods; but it must be altogether under water, as partial immersion is very destructive.

"Of steeping generally, whether in cold or warm weather, it must be observed, that it dissolves the substance of the wood, and necessarily renders it lighter; therefore the less that is necessary of it the better; indeed, it is known, that, notwithstanding wood that is completely submersed remains good for a very great period after the water has dissolved a certain soluble part, it is, when taken out and dried, brittle, and in every respect unfit for use.

"For the purposes of joinery, steaming and boiling are very good methods, as the loss of elasticity and strength which they produce, and which is so essential in carpentry, is compensated by the tendency to shrinkage being reduced; the durability also is rather improved than otherwise, at least from steaming. It has been ascertained, that of woods seasoned by these methods, those dry soonest which have been steamed; but the drying in either case should be somewhat gradual, and four hours are sufficient for the boiling or steaming process."

Langton's method of seasoning by extraction of the sap, is another that is considered well worthy of notice; it consists in letting the timber into vertical iron cylinders at top; and the water being heated, and steam used to produce a partial vacuum, the sap relieved from the atmospherical pressure oozes from the wood, and, being converted into vapour, passes off through a pipe provided for the purpose. The time required is about ten weeks, and the cost is about ten shillings per load; but the sap is wholly extracted, and the timber fit and ready for any purpose; the diminution of weight is, with a little more shrinking, similar to that in seasoning by the common natural process.

Smoke-drying in an open chimney, or the burning of furze, fern, shavings, or straw under the wood, gives it hardness and durability; and by rendering it better, destroys and prevents worms; it also destroys the germ of any fungus which may have commenced. Scorching and charring are good for preventing and destroying infection, but have to be done slowly, and only to timber that is already thoroughly seasoned; otherwise, by encrusting the surface, the evaporation of any internal moisture is intercepted, and decay in the heart soon ensues; if done hastily, cracks are also caused on the surface, and which receiving from the wood a moisture for which there is not a sufficient means of evaporation, renders it soon liable to decay.

Various methods have been from time to time proposed for seasoning timber, and preventing its rapid decay; but those which have most engrossed the public attention of late years, are those respectively distinguished as Kyan's, Payne's, Burnett's patents, &c. In the year 1833 to 1836, at the Arsenal, Woolwich, experiments were instituted, having for their object the establishing or otherwise the claims of that first mentioned, and the results of which were of a very satisfactory nature; the Kyanised specimens generally, which were submitted to the fungus-pit when taken out at the end of three years, being sound, while duplicate pieces unprepared were found in various stages of decay. Certain questions, however, presented themselves:—1st. Whether the impregnation to which the timber had been subjected, might not be removable by some cause, and perhaps generate an atmosphere noxious and injurious to health. 2nd. Whether the strength of the timber were impaired or otherwise. The first was satisfactorily determined by Dr. Faraday, who proved by experiment, that the combination was not simply mechanical, but chemical; and that a permanently compound material was formed; the second was formed by experiments made by Captain Alderson, C.E., upon ash and Christiana deal, and which showed that the rigidity of the timber was enhanced, but its strength in some measure impaired, its specific gravity also being somewhat diminished. Another question yet remains open—how far, since the impregnation has not been traced to a depth greater than half an inch, does this process meet our requirements, and after the satisfactory conclusion arrived at as above related, and the evidence of the facts upon which it was so reasonably founded, how are we to meet the assertion of Mr. Pritchard, C.E. of Shoreham, made in 1842. The sleepers Kyanised five years ago, and in use at the W. I. Dock warehouses, have been discovered to decay rapidly, and the wooden tanks at the Anti-Dry-Rot Company's principal yard are decayed.

Mr. Kyan's infusion is corrosive sublimate, and the process consists in submersing the timber in tanks for about a week, then taking it out and drying. Sir Humphrey Davy had previously recommended a weak solution of the same thing, to be used as a wash where rot had made its appearance. Dr. Birkbeck made a favourable exposition of the process as pursued by Mr. Kyan. Sir John Barrow and the Duke of Portland impugn it, and Lord Manners and Dr. Moore follow on the same side. The Payanising process, besides professing to preserve timber from dry-rot and the ravages of insects, is said to render it uninflammable, or at least to deprive it in a great measure of combustibility.

Sir William Burnett's patent process seems to have met with great, and, as we think, deserved success. The various testimonials that we have seen in favour of it, and the time that it has maintained itself in the opinion of the public, induce us to think well of its efficacy in performing what it professes to do. Even if not quite realizing all its inventors claim for it, it certainly will effectually preserve timber for a great number of years. The effects ascribed to it are, that it hardens and improves its texture. It enters into permanent chemical combination with the ligneous fibre, and does not come to the surface of the wood by efflorescence, like other crystallizable salts, and no amount of washing or boiling in water, will remove the chemical compound so formed. It preserves wood and other articles from the adherence of animal and vegetable parasites, and also from the attacks of insects, and from *wet* and *dry* rot. Further, it renders wood uninflammable, when used of a certain strength. The basis of his process is chloride of zinc, or, as it is more commonly called, the muriate of zinc, which seems to have a peculiar affinity to woody fibre, entering into intimate union with its component particles, and forming as it were a new mineralized substance. There is a chemical combination of the metallic base; not merely by a mechanical alteration of the position of matter, which might again be disunited. There is no decomposition produced, but the fibre of the wood appears to be permanently pervaded by the zinc, and the atoms of which they are formed enter into a new and fixed arrangement.

SECANT, (from the Latin *seco*, to cut,) a line that cuts another, or divides it into two parts.

In trigonometry, the secant is a line drawn to the centre from some point in the tangent, which consequently cuts the circle.

SECRETARIUM, the vestry of a church, the same as Sacristy.

SECTION OF A BUILDING, a representation of the building as divided or separated into two parts, by a vertical plane, in order to explain the construction of the interior. The section of a building not only includes the parts that are separated, but also the elevation of the receding parts, which ought, therefore, to be shadowed with a darker tint. It is obvious that the section of a building ought to be taken so as not only to show the greatest number of parts, but also those that present the most difficulty in their construction. Every building ought to have at least two sections, at right angles to each other, and parallel to the sides of the building: a section of the flues will also be necessary, in order to conduct the interior walls, and to avoid the improper placing of timbers, or mistakes that might otherwise unavoidably take place.

SECTION OF A SOLID, the place of separation that divides one part from another; it is always understood to be a plane surface. *See* STEREOTOMY.

SECTIONS, *Conic*, see CONIC SECTIONS.

SECTIONS OF CYLINDERS, see CYLINDERS.

SECTOR (from the French *secteur*), an instrument for measuring or laying off angles, and for dividing straight lines and circles into equal parts. *See* INSTRUMENTS.

SECTOR OF A CIRCLE, the space comprehended between two radii and the arc terminated by them.

The area of a sector is found by multiplying the radius of the circle into half the arc of the sector.

SEDILIA, seats for the officiating clergy, frequently to be found in the south wall of the chancel of our old churches. They are usually arched recesses in the wall, and are often surmounted by canopies and richly decorated with carving, and sometimes quite plain. They consist of a series of from one to five arches, for so many priests, the usual number being three. The seats are sometimes level, but frequently graduated, following the level of the chancel steps; they are occasionally formed in the sill of a window.

SEGMENT (from the Latin *segmentnm*, a shred or paring), any part of a whole.

SEGMENT OF A CIRCLE, the area comprehended by an arc and a chord.

All angles in the same segment are equal.

A very useful practical rule for finding the area of the segment of a circle is the following:—multiply the chord into the versed sine; then, to two-thirds of the product, add the quotient arising by dividing the cube of the versed sine by twice the chord. *See* MENSURATION.

SELL, the lowest piece of timber in a building. *See* SILL.

SEMICIRCLE, the half of a circle contained by the diameter and the circumference.

The angle in a semicircle is a right angle.

The arc of a semicircle is, of course, half of the circle. *See* CIRCLE.

SEMICIRCULAR ARCHES, arches constructed with semicircular arcs. They were much used by Roman architects, particularly in the decline of the Roman empire; and also by the Saxons and Normans in England, and their successors, until they were superseded by the pointed arch: they were again brought into use by the introduction of Roman architecture, in the time of Inigo Jones.

SEPTIZON, or SEPTIZONIUM, in ancient architecture, a term almost exclusively appropriated to a celebrated mausoleum of the Antonines, which, Aurelius Victor says, was built in the tenth region of the city of Rome, being a large insulated building, with seven stages, or stories, of columns.

The plan was square, and the upper stories, consisting of columns, falling back much, rendered the pile of a pyramidal form, terminated at the top with the statue of the emperor Septimius Severus, who built it.

It had its name Septizon, or Septizonium, from *septem* and *zona*, *q. d.*, seven zones, or girdles, by reason of its being girt with seven rows of columns. Historians mention another Septizon, more ancient than that of Severus, built near the Thermæ of Antoninus.

SEPULCHRAL (from the Latin *sepulchrum*, a tomb, or place for burial), something relating to sepulchres or tombs.

SEPULCHRAL CHAPEL, or chapel containing a tomb or sepulchral monument, or in which masses were chanted for the repose of the departed, and in this sense the same as CHANTRY CHAPEL. Such buildings were usually appended to churches, and formed a small kind of aisle.

SEPULCHRAL COLUMN, see *Funeral Column*, under COLUMN.

SEPULCHRAL MONUMENT, a monument erected to preserve the memory of some deceased person. They are of various designs at different dates and places; but probably those of the middle ages in this country will never be surpassed in beauty of conception or delicacy of workmanship. Many fine examples are to be found in our cathedrals. Amongst the most beautiful are those of Wykeham and Waynflete, Winchester.

SEPULCHRE (from the Latin *sepulchrum*, a tomb), or place destined for the interment of the dead. The word is chiefly used in speaking of the burial-places of the ancients: those of the moderns are usually called *tombs*.

Besides the usual sepulchres for the interment, either of the whole body, or of the ashes of such as were burnt, the ancients had a peculiar kind, called *cenotaphia*, which were empty sepulchres, in honour of some persons who, perhaps, had no burial at all, from a superstitious opinion, that the souls of those without burial wandered a hundred years before they were admitted into the Elysian fields. The pyramids are generally supposed to have been built as sepulchres for the kings of Egypt, and the obelisks were erected as mementos of eminent persons deceased.

In our old churches is frequently found, at the east end, usually on the north wall of the chancel, a sepulchral monument, enclosed in an arched recess. This is called the altar-tomb, as also the holy sepulchre, or Easter sepulchre, from the circumstance, that, previous to the Reformation, certain ceremonies were performed here between Good Friday and Easter-day. It is not unfrequently the tomb of the founder of the church.

Such tombs are frequently of very elaborate design, and enriched with sculpture and colour. Two magnificent specimens exist in the presbytery of Westminster Abbey.

SERAGLIO, among Oriental builders, the palace of a prince or lord. By way of excellence, the term is used for the palace of the grand signor at Constantinople.

SERLIO, SEBASTIANO, an eminent architect, a native of Bologna. He flourished, at Venice, in the early part of the sixteenth century. He afterwards travelled through Italy, and resided a considerable time at Rome, where he studied the fine arts, and made many excellent drawings of edifices, ancient and modern. He is said to have been the first who examined, with a scientific eye, the remains of ancient architecture. The knowledge he acquired was given to the public in *A Complete Treatise of Architecture*, of which he planned seven books; and the first that appeared was the fourth in order, comprehending the general rules of architecture, which he printed at Venice in 1537, dedicated to Hercules II., duke of Ferrara. The other six books appeared successively at different intervals; and the various editions

made of them prove their popularity. In 1541, Serlio was invited to France by Francis I., and employed in the erections at Fontainebleau. Here he continued till he died, at an advanced age, in 1578. Though, as an author, he was much attached to the principles of Vitruvius, yet, in his designs as an artist, he very much neglected them. His school at St. Roche, and palace of Grimani at Venice, are built in a grand and magnificent style.

SESSPOOL, or CESSPOOL, a well, or deep hole, sunk under the mouth of a drain, for the reception of sediment, and other gross matter, which, if not there detained, would choke the passage. Sesspools ought to be so contrived, that they may be cleaned without difficulty; otherwise they will fill up, and the evil be communicated to the drains.

SET-OFF, that part of a wall where the face is broken by a projection beyond the general surface, such as where the lower portion of a wall is of greater thickness than the upper, and therefore leaves a ledge at the height where the lesser thickness commences, equal in width to the difference in thickness of the two portions of the wall. This practice is very usual in buttresses, and almost universal in those of mediæval date. Such ledges are usually covered with a sloping table of masonry to carry off the wet, and are termed *set-offs*.

SETTING, a term used in masonry, for fixing stones in walls or vaults. In this the utmost care should be taken that the stones rest firmly upon their beds, and that their faces be ranged on the proper surface of the work. This caution is necessary, as bad workmen, in order to make close joints, only make the beds come in contact adjacent to the face of the work; and, in order to bring the joints flush, they frequently do no more than round the work next to the joint: this convexity has a very disagreeable appearance in the sunshine, when the rays of light fall obliquely upon the work.

SETTING-OUT ROD, the rod used by joiners for setting out windows, doors, or other framing.

SEVERY, a bay or compartment; especially applied to the compartments of vaulted roofs.

SEWER, a large main drain, conduit, or conveyance for carrying off refuse, or soil, from a house, or number of houses.

SEWERAGE, the method of removing superfluous water, rain, filth, night-soil, and other refuse matters from a town or other locality.

The subject connected with this article, is of very considerable importance, as it affects the health, morals, and social well-being of the community; as it is now universally allowed, that the accumulation of refuse matter is dangerous to health, and especially in crowded and densely-populated districts, where it is certain to encourage, if it does not generate, various kinds of epidemic disease; besides which, it discourages habits of cleanliness, and so affects the morals of the lower orders. It is a matter which formerly was not sufficiently attended to; but has of late years forced itself upon public notice, and is at the present day receiving that amount of consideration which it so well deserves.

Although, however, the matter has been widely canvassed, and much elaborate investigation entered into, we regret to say, that hitherto, mere matters of detail have received comparatively more attention than they deserved, and general principles have been too much overlooked; not that we would for a moment undervalue the investigation which is being carried on with reference to minutiæ, which are indeed of the utmost importance; but we think that general principles should have had the first place in the order of investigation. Be this as it may, we must confess, that much useful and practical, as well as theoretical knowledge, has been eliminated by the process, and many improvements introduced which are of considerable public benefit. This branch of professional practice is as yet in its infancy, and we may hope that a few years will add considerably to our practical and theoretical acquaintance with it, when theories, which are now only upon trial, shall have been fully and fairly tested, and some further inquiry entered into with respect to the objects which are sought after, in laying out the drainage of a town.

In considering this subject, a question naturally arises at the very outset, as to the objects to be effected by proper drainage of any locality. Now, formerly the object, for there was but one, was very well defined, and very simple; it was this, to remove the refuse from the neighbourhood of inhabited districts, so that it might not become prejudicial to the health of the inhabitants. Within the last few years, however, some new data have been introduced, and in consequence the question has become more complicated. The inquiry has been mooted as to whether it be advisable to throw away as useless the collected refuse, or whether it may not be employed to some useful purpose; and if so, whether it may not be turned to account as a profitable article of commerce. Many subjects have been named, in the manipulation of which, such matters might be advantageously employed; but of all these, the most important, and that which has the highest claim to consideration, seems to be their application to agricultural purposes, in the shape of manure. Whether indeed the refuse of towns is of value for this purpose, has been, and still is a matter of dispute amongst persons well qualified to judge; but we think the evidence in favour of such application decidedly preponderates.

The value of manures as promoters of vegetation, is said to result from their possession of the essential element, nitrogen, in the form of ammonia, with the subordinate properties of alkalies, phosphates, and sulphates, and we learn from the experiments of Liebig, that the quantity of nitrogen contained in the excrements of a man during one year, is 16.41 lbs., and also that this quantity is sufficient for the supply of 800 lbs. of wheat, rye, or oats, or of 900 lbs. of barley. "This is much more," says the same authority, "than it is necessary to add to an acre of land, in order to obtain, with the assistance of the nitrogen absorbed from the atmosphere, the richest crops every year. By adopting a system of rotation of crops, every town and farm might thus supply itself with the manure, which, besides containing the most nitrogen, contains also the most phosphates. By using at the same time bones and the lixiviated ashes of wood, animal excrements might be completely dispensed with on many kinds of soil. When human excrements are treated in a proper manner, so as to remove the moisture without permitting the escape of ammonia, they may be put into such a form as will allow them to be transported even to great distances." Of the success of sewage matters applied as manure, we have favourable evidence in the practice adopted at Edinburgh, where the pasture-land has been made to produce crops very considerably above the average by this means. Experiments of an equally favourable description have also been tried in various parts of this country, as well as on the Continent; at Milan, and various parts of France and Germany. These, however, only speak as to the success of such manure in a liquid form, against which one or two practical objections may be urged. The first is the expense of distribution; for, in the first place, the sewage waters must be raised to a considerable elevation by artificial means, for the purpose of conveying them on to the surface of the surrounding districts, and this elevation will be greater or less according to the level of the neighbourhood. The second objection consists in the limited area

to which such a manure could be advantageously applied; for if the distance were great, the necessary outlay for conveyance would form an effectual obstacle to its employment. Of a similar nature to the last, is the objection which arises from the uncertainty of the demand; for in wet seasons, the manure in this condition cannot be applied; and if at any time the soil be supersaturated, the vegetation is supposed to be injured thereby. Besides, if the sewage be allowed to remain on the surface, it will emit very offensive and injurious odours, and become not only detrimental to the land, but highly dangerous to the public health.

To meet these evils, several methods have been suggested for precipitating the valuable portions of the sewage, and preparing them in a dry state for the purposes of commerce, during which process the matters are also de-odorized and disinfected. It is a matter of dispute, indeed, whether the portions of sewage which are specially serviceable for agricultural purposes can be preserved in a dry form; but besides the evidence resulting from experiments with this form of manure, we have the favourable testimony of Liebig, who thus writes:—"Gypsum, chloride of calcium, sulphuric or muriatic acid, and super-phosphates of lime, are substances of a very low price; and if they were added to urine until the latter lost its alkalinity, the ammonia would be converted into salts, which would have no further tendency to volatilize. When a basin, filled with concentrated muriatic acid, is placed in a common necessary, so that its surface is in free communication with the vapours arising from below, it becomes filled, after a few days, with crystals of muriate of ammonia. The ammonia, the presence of which the organs of smell amply testify, combines with the muriatic acid, and loses entirely its volatility, and thick clouds or fumes of salt hang over the basin." And in the quotation which we have previously quoted, the same chemist states his opinion, that the moisture may be removed without permitting the escape of ammonia, and the sewage put into such a form as to allow it to be transported to great distances. In opposition to this, some persons have asserted, that where the smell does not exist, the fertilizing property has been lost; and others, that although the offensive odour is got rid of, the deleterious properties still remain. These opinions are indeed destructive of each other, and we are inclined to yield the greater amount of credit to Liebig's testimony. Mr. Richard Dover, who propounded a scheme for disinfecting the London sewage, and preparing it for transport in a dry state, made some experiments upon sewage-water taken from the Northumberland street outlet, in the presence of several persons competent to form a judgment on the subject, and who testify to having been satisfied as to the success of the experiment. Manure prepared by this process has been experimentally applied to agricultural purposes, and, it is said, with very satisfactory results. Mr. Dover further proposes to apply the water, which is left, for the purpose of bleaching and other commercial undertakings.

Such are the statements with regard to the employment of sewage-matters for agricultural purposes: that they are useful fertilizing agents, there seems to remain no reason to doubt; but there still does remain a question as to whether it can be profitably employed for this purpose, considering the subject in the light of a commercial undertaking. Can it compete with other manures already in the market, or will the expense of its manipulation destroy its value as a marketable commodity. These questions still remain to be considered; for although the evidence which does exist seems to favour the speculation, yet this is not sufficiently decisive to justify an undertaking of the kind on a large scale.

Now the very first principles of drainage depend upon the resolution of such doubts; for if the sewage-matter is to be thus employed, we should adopt a very different system to that which would be adopted, had we solely to get rid of the noxious refuse. There would be also a difference of treatment, according to the condition in which the manure was to be applied, whether in a wet or dry state; for in the one case we should be tied down to the most economical method of distributing it over the surrounding country by means of pipes, and should have to regulate our levels and outlets accordingly; whereas, under the latter conditions, we should be left at much greater liberty in arranging such preliminaries.

In the first place, if we treat sewage matters as only deleterious to public health, and incapable of being turned to any useful account, we have to deal with a very plain and simple question; our sole object is to get rid of it. Simple, however, as may be the object to be attained, it is by no means easy of attainment; and of the two cases, this is probably the most difficult. We are well aware that we cannot annihilate the elements of which the matters are composed, however much we may be able to alter their combinations, and perhaps destroy their characteristic qualities. Granting, then, that the noxious properties of the soil can be removed, we find two courses open to us, either to disinfect it, and then dispose of it in any manner most suitable to the locality, or else to remove it, in its primary state, to a distance from human habitation. If we adopt the former course, we may disinfect it either during its passage to its outlet, or may collect the various streams into one or more reservoirs, as the nature of the locality may render advisable, and there disinfect it; after which there will probably be no difficulty of disposing of it, either by conducting it into a river or running-stream, or by some other means which the nature of the place may suggest. If the latter expedient be resorted to, we shall have much greater difficulties to encounter, for we can scarcely consider it inoperative for evil, until it is safely and fairly launched into the wide ocean; until it has arrived at this point, we are not secure against its fatal influence. This, however, is no easy matter to accomplish: to effect the object in view, we instinctively look for some natural channel, by means of which it may be conveyed to its proposed destination, and this is presented to us in the shape of a stream or river; to conduct it to the sea by artificial means, would, in the majority of cases, be entirely out of the question, on account of its enormous expense; we must therefore adopt the river as a last resource. We are well aware that this is objectionable on many accounts; but if we are compelled to get rid of the offensive matter, we would ask, what other method of effecting this object remains open to us. We know the question will arise, as to whether under such circumstances the sewage ever reaches its destination; and it would be very difficult to answer positively that it does, and therefore probably we must rest content with a palliative measure, and remove it from the more densely populated districts only. Where there is a good river, not a tidal river, this may be effected readily, for the sewage discharged into the river will be conveyed with its waters in an onward course without interruption, depositing probably some of its heavier particles, but not in such large quantities as to become dangerous. In a tidal river, however, the state of the case is altered, for although we have the advantage of the ebb-tide in conveying the refuse towards the sea, we have the corresponding disadvantage of the flow bringing it back again.

It has been suggested with reference to the drainage of London by the Thames, that as the flow is of only 5 hours' duration, and the ebb of 7, and that during that time the range of flux is 7 miles, and reflux 10, therefore a progres-

sive movement of 3 miles is made towards the outlet every ebb and flow. This conclusion has been arrived at without sufficient data, for it has since been established by actual experiment, that not only is there a progressive and retrograde motion going on every tide, but that the same process takes place with a series of tides, and that after a float has made a certain progress down the river by the excess of the flux over the reflux, it turns, and makes an actual retrogression up the river, by the excess of the reflux over the flux, until it arrives once more nearly up to the point whence it started.

From this it will appear that, in a tidal river, there will be a great difficulty in carrying refuse matters to sea, or even from the vicinity of towns, if it be allowed to discharge at or near the town; it will constantly be carried about backwards and forwards, and depositing its solid matters in the bed, or on the banks, of the river. The sole remedy for this seems to be, to extend the sewer to such a distance from the town for discharge, that the tide may not at any time be able to carry it back near the town. Another object will be, to make the discharge at high-water, or as near high-water as possible, so that it may have all the advantage of the first ebb. This, however, is not always practicable in low-lying districts, unless, indeed, we employ artificial means for raising it ere it reaches the outlet.

Let us now consider the question under another aspect; supposing the refuse to be turned to acconnt for agricultural purposes: this, although somewhat more complicated, we shall probably find more easily dealt with than the previous case. The question again resolves itself into two distinct parts,—the first where the sewage is used in a liquid state, the other where it undergoes a preparation previous to use, and is applied in a dry state,—and these two will require somewhat different treatment. The first arrangement, where the manure is expended entirely upon the surrounding neighbourhood, must depend, in a great measure, upon the character of the neighbourhood, and the comparative levels between it and the town to be drained. In this case it will be advisable to divide the town into different drainage levels, corresponding with the general or average altitudes of each distinct level of the adjacent country, and provide each drainage level with a separate outlet, situated as near the corresponding level of the adjacent land as may be in other respects convenient. By so doing we shall dispense to some extent with the use of pumps, and other expensive contrivances for raising the manure; we shall also save a considerable amount of excavation, and avoid very large main sewers. It must not be supposed, that here, or in any other places in this article, we lay down fixed rules of universal application, but rather throw out hints which may be found generally useful; the peculiarities of each particular locality must decide the method of drainage; there may be some localities where the above directions may not only be unadvisable, but simply impracticable, and we only bring them forward that they may not be left out of consideration in any instance, and may be adopted when found to be eligible. It is useless to think of laying down positive rules in such cases, where the nature of the subject to be treated of must necessarily vary in individual instances.

The last case which we have to consider is, when the sewage is to be applied for agricultural purposes in a dry state, and this will, we think, prove to be the most simple of the three. We have here only to collect the sewage, and conduct it into one or more tanks, in such situations as may be most convenient, where it will undergo a process of disinfection, and will be precipitated, or solidified for the purpose of conveyance to such lands as may require it, either in the neighbourhood, or at a distance. It will be advisable that the tanks be at some distance from the town, to obviate any danger or inconvenience which may arise during the preparation; and it is further to be desired, that they should be near a canal, river, or railway, so as to present facilities for carriage to distant localities; it would be well if they could be placed in proximity to both rail and river, for while the former will be very convenient for the purpose of conveyance, the latter will be further useful for the discharge of the sewage-water which remains after the extraction of the solid matter, if, indeed, it be not applied to some more useful purpose. This water may be discharged into the river without inconvenience or danger, for if not already sufficiently purified, it would be no difficult matter still further to purify it by filtration. If a ready means of discharge for the supernatant water be provided, the size of the tanks may be greatly diminished, and in the same, or rather greater, proportion, the expense and difficulty of their construction.

We have now considered the subject as regards the three different methods of disposal of the refuse most likely to occur in practice. We must again express our regret that greater labour has not been bestowed on the question of the practicability of the two last methods, yet at the same time we must take occasion to remind the reader, that even had this question been generally disposed of, it would not follow that any particular practice would be advisable in every individual case. The proper determination of the method to be adopted, must be the result of a careful investigation of the nature of the several districts to be drained; one method may be convenient in one place—another, a different one, in a second. We have here considered the subject solely as regards the disposal, and principally with reference to outlets, as these are the most affected by the various methods of disposal; let us now turn to the principles of town-drainage generally.

The first thing to be done in laying out a system of drainage, is to prepare a carefully surveyed map of the district to be drained, showing at least the main levels: at the outset, perhaps a block plan will be sufficient; but before the question is finally determined upon, and details entered into, it will be necessary to have the blocks filled in. To do this, it will be requisite that the map be on a sufficiently large scale; that adopted by the Ordnance Survey, five feet to a mile, or one somewhat larger, will be found convenient, and on this, additional levels must be laid down before entering into detail. It will be advisable ere commencing the consideration of the subject, to prepare from this a map on a reduced scale, containing in addition some considerable portion of the surrounding country, so that the consideration may not be confined to a limited space, without reference to the circumstances of the more immediate neighborhood; by so doing, much future trouble and expense may be avoided; by all means let the consideration of the subject be comprehensive. It will greatly assist, if the contour-lines be laid down on this map, so as to afford at a glance a tolerably accurate idea of the nature of the ground. It will be further necessary to obtain information respecting the geology of the district, as well for matters of construction as for other purposes, and also some general notion of the nature of the soil with reference to agricultural matters, in order to determine the extent to which the town-refuse may be employed as manure in the immediate vicinity. These, however, and other matters necessary to be known, will naturally suggest themselves to those engaged in such works.

The surveyor having made himself thoroughly acquainted with the character of the district to be drained, will be in a proper position to determine the system upon which to commence operations. The practice of our predecessors has been, to

collect the sewage matter, and convey it by the shortest route to the nearest river, into which it was to discharge; this done, their object was attained; the matter was left to remove itself, or deposit on the banks or bed of the river, as best it might. This method is now generally allowed to have been based upon false principles; but it must at the same time be confessed, that to a certain degree it did follow out the course suggested by nature. That the drainage should be carried towards the river, is not to be objected to; for it amounts to nothing more than conveying it to the lowest level of the district; it is the very course which nature adopts, for rivers and streams are indeed the drains laid out by nature; the only mistake consists in polluting these waters with matters which are prejudicial to health; had we only to deal with surface-drains, the system would be rational enough. Some persons, because this method has been abused, have thought it right to discard it altogether; we cannot follow them thus far; if the area to be drained presents throughout one general slope towards the river, we are inclined to think that this would be the most suitable method of drainage, having the outlet or outlets at the lowest level. If the sewage is to be supplied in its liquid state to the surrounding country, it may be advisable to intercept a portion ere it reaches this point, but this the circumstances of each case must decide; by such means we should of course be better able to irrigate the higher lands, and should also effect a saving in the size of our sewers, for the lower branches will not have so large a quantity to discharge.

If again the levels of the main be greatly diversified, or especially if it consist of basins surrounded by higher ground, it would appear advisable, under any of the above conditions, to provide a separate drainage for each level, so as to avoid the great depth of excavation which would be necessitated, were the drainage of the higher levels to be connected with a main which had already received that of a lower level. The better plan would be to convey this line through the lower levels to its outlet, and to form a separate system for the higher grounds. Whether it would be advisable to drain all the low levels together by one trunk-line, and all the high levels by another, or to drain each level separately, must be determined by the circumstances of each special case; as we said before, no fixed rules can be laid down, we can only propose useful hints to be applied as the nature of each case suggests.

Having disposed of these general matters, we now come to consider the subject more in detail; but before doing so, let us clearly understand, and determine what we have to do, and what class of subjects we have to deal with. Our general object is to convey to a distance the refuse, or a certain portion of the refuse, of the town, or other area to be drained, and what does this consist of; it is mainly of two descriptions, viz., that which may be particularized as house-drainage, consisting of the excrements of the inhabitants, and all refuse matters connected with household economy; and that which is distinguished as surface-drainage, which has especial reference to rainfall and storm-waters. Formerly it was the custom to make no distinction between these two descriptions; but of late, we have begun to consider them as separate items, and a grand question has been raised as to whether it is correct to provide for them both by the same system of drains. In the one case, the supply is, or might be, made tolerably uniform; in the other, it is periodical and uncertain, nor can it be made otherwise; it therefore becomes a question, whether the two can be advantageously combined, but as the inquiry is so mixed up with the determination of the size and shape of sewers, it will be better to consider it under that head. We have made no allusion to subsoil drainage, for it is indeed very rarely required; if the surface be properly drained, there will be no necessity for subsoil drainage, except in cases where springs exist, or where the strata contain water, and, even in such cases, it is questionable whether the water might not be usefully employed, rather than carried away at a considerable expense. We shall leave this part of the subject therefore out of the question, and turn at once to the consideration of the sizes and forms of sewers.

Until the last few years, it was the custom to construct sewers of a very large size, varying in sectional area from 5 to 100 feet, the former being allotted to collateral sewers in courts, alleys, and side-streets, and the latter to the main outlets into the Thames, the average area for main lines being about 12 feet. Now, the fact is, that these sewers were seldom, if ever, fully charged, the sectional area of the stream usually flowing through them, averaging not more than $\frac{1}{10}$ part of the area of the sewer, and the flow being often scarcely perceptible. In continuous wet weather, the area of sewage was greatly increased; and also on such days as fresh water was supplied to the houses; in neither case, however, was the sectional area equal to $\frac{1}{4}$ that of the sewer, and the only occasion on which the sewers were anything like full, was the occurrence of some very heavy storm, such perhaps as does not appear once in the course of a twelvemonth. Now, it appeared to those who have recently brought forward this subject for investigation, that a much smaller size would answer the purpose much better, and be decidedly much more economical in construction. Under this impression, several experiments were made under the Metropolitan Sewage Commission, to test the fact, and the result appears to have been decidedly favourable to the new theory.

In a main line of sewer in Upper George-street, Edgeware-road, which communicates directly with the King's Scholars' pond sewer, and which is 5 feet 6 inches in height, by 3 feet 6 inches wide, an earthenware pipe 12 inches in diameter was inserted, laid immediately upon the invert of the larger sewer, and a head-wall built up above it in the sewer, for the purpose of preventing any sewage-matter passing out by a different channel. The total length of this pipe measured 560 feet, and the whole area drained through it amounted to about 44 acres. The results are stated to have been as follows:—"The velocity of the stream in the pipe has been observed to be $4\frac{1}{2}$ times greater than the velocity of the same amount of water on the bed of the old sewer. The pipe has not been found to contain any deposit, but during heavy rains the stones have been heard distinctly rattling through the pipe. When the pipe is nearly filled, the velocity and concentration of the water are sufficient to clear away any matter which may have been drawn into the pipe from the large sewers, much of which matter, it may be presumed, would never enter a well-regulated system of pipe sewers; also the force of the water issuing from the end of the pipe, is sufficiently great to keep the bottom of the old sewer perfectly clean for 12 feet in length; beyond this distance, a few bricks and stones are deposited, which increase in quantity as the distance from the pipe increases. Beyond a certain distance, mud, sand, and other deposits, occur to the depth of several inches, so that the stream there is wide and comparatively sluggish, and being dammed by the deposit, exerts an unfavourable influence on the flow of water through the pipe. On the invert of the original sewer, which now forms the bed of the pipe, deposit was constantly accumulating, and was only partially kept under by repeated flushes. The superficial velocity of the water in the pipe is generally three, four, and five times greater than the superficial velocity which obtained, under the same circumstances, in the original sewer, and the velocity of the whole mass of water

in the pipe approximates much more to its surface-velocity, as ascertained by a float, than does the velocity of the whole mass of water in the sewer approximate to its own surface-velocity."

Several experiments in this pipe were also made, to determine the propulsive force exerted by the water in removing obstacles, and it was found that quantities of sand, mud, and pieces of brick and stones, were carried from the inlet through the entire length of the pipe, where they were discharged with considerable force, and carried some distance along the invert of the original sewer. All these experiments were effected when the pipe was only or less than half-full of water. The period of year at which the experiments were made, was principally during the month of October, and the following is the detailed daily account of the depth of water in the pipe:—

September 28 and 29. Very wet both days and nights; there was at this period 96 hours' continuance of rain, and the pipe was never observed to be more than half-filled.

October 19. Morning, depth of water in pipe 3 inches; afternoon, depth 2 inches.

October 21. Heavy rain all day; depth of water in pipe 4 and 5 inches.

October 23. Morning, 3 inches; afternoon, very heavy rain, when the pipe filled.

October 24. Morning, depth varied from 2 to 2½ inches; afternoon, from 2½ to 3 inches.

October 25. During the day, depth of water varied from 2 to 2½ inches; afternoon, from 2½ to 3 inches.

October 26. Morning, depth varied from 4 to 3 inches; afternoon, from 2½ inches to 3 inches. During the above three days, the weather was mostly fine. The considerable variations are due to the times of the water being on at the houses; the sewage at such times is much clearer, as well as increased in quantity.

October 27. On this day a storm occurred, which, for a short period, was very violent; the waters filled the pipe, and rose above it 18 inches, but did not reach the top of the head-wall; when the waters had reached this maximum height, they receded to nearly the level of the pipe in twenty minutes.

October 28. Depth during day varied from 3 inches to 1½ inches.

October 30. Depth during day varied from 2 inches to 2½ inches.

October 31. Depth during day varied from 1½ inches to 2 inches.

November 1. Variation of depth from 1½ inches to 2½ inches.

November 2. Variation of depth from 2 inches to 2½ inches.

Another series of experiments was very carefully superintended by Mr. Lovick, Surveyor to the Commission, in Earl-street, Marylebone: the original sewer presenting a sectional area of 15 feet, and having a flat segmental invert 3 feet in width, in which deposit accumulated at the rate of 6,000 cubic feet in 31 days. The area draining into this sewer was 43.656 acres; and the number of houses drained 1135. Upon the invert of this sewer, a 15-inch glazed stone-ware pipe was laid for a length of 115 feet, and having an inclination of 1 in 153.

From these experiments, it appeared that the average consumption of water was about 5.7 gallons per individual per day, or 51½ gallons per house per day; the average quantity discharged when there was no rain, and no fresh supply of water, was 44½ gallons per house per diem; and on the days when the water was supplied to the houses, 209 gallons per house per day. Thus the mean flow on the days when water was supplied to the houses by the water companies, was nearly 4¾ times greater than the mean flow on ordinary days, or days when there was no supply.

The annexed table, deduced from those experiments, will give a correct idea of the several conditions of discharge on ordinary and water days:—

Days.	Quality of Flow.	Cubic feet per minute.	Sectional area of flow in pipe.	Diameter of circles, equal in area to the sectional area of flow.
			Inches.	Inches.
On ordinary days.	Least	1.78	3.05	2.00
	Mean Least	2.10	—	—
	Mean	5.64	8.57	3.4
	Mean Greatest	16.90	18.14	4.9
	Greatest	46.50	—	—
On water days.	Least	1.07	1.66	1.5
	Mean	26.46	27.94	6.00
	Mean Greatest	106.00	—	—
	Greatest	150.00	109.79	11.8

The maximum being greater than the minimum, on the water days 140 times, and on ordinary days 26 times. The experiment was continued for 30 days, 16 of which were water days, and the remaining 14 ordinary days, and the period of the year at which it took place was during the months of February and March. The *least flow* in the above table refers to the least flow which occurred at any one time during the range of observations; the *mean least*, to the average of the lowest discharges of every day; the *mean*, to the average of the mean of all the observations; so also of the *greatest* and *mean greatest*.

As an evidence of the false principles on which the old system was based, the same surveyor states that the sectional area of the drains in this block of houses was 596 feet, whereas the sectional area of the outlet sewer was only 15 feet, or about one-fortieth the aggregate sectional area of the house-drains. He also states, as the result of his experience generally, that blocks of houses drained with 3, 4, 6, and 9-inch pipes, have been more efficiently drained than under the old system.

The same opinion, with reference to the size of sewers, was given by Mr. Phillips, also Surveyor to the Metropolitan Commission and the late Westminster Commission, in his examination before the Sanitary Commissioners; but he considers a constant supply of water indispensable, if smaller sizes be adopted. In answer to the question—

"Have you at all considered the capacities of sewers necessary for draining the different areas of ground?" he replies, "Yes; I have given the subject much attention. If the consideration of the sizes of sewers was confined solely to the carrying off the water supplied by the several water-companies, then I apprehend that pipes somewhat larger in size than the supply-pipes themselves, would suffice; but provision has to be made for receiving and carrying away the waters of heavy rains. In London, continuous heavy falls of rain are not of long duration, lasting seldom more than from one to four hours. About one-fifth of the quantity that falls, is absorbed partly by the dryness of the surface of the roofs, the paving, and the ground, and partly by the porosity of the ground itself. A farther proportion is also prevented from flowing to the drains and sewers at all by hollows in the surface, and again reascends into the atmosphere as vapour. There is also a small quantity that enters into the composition of animal and vegetable bodies. Then

there is the resistance the flow experiences from the friction of the entire surface, being accelerated or detained in proportion as the surface is more or less inclined. To provide for the discharge of a fall of rain of two inches in depth, has been considered by Mr. Hawksby, C. E., the extreme datum upon which to proportion the capacities of town-sewers generally. Now I believe that, practically, the sizes in his table, although they may appear theoretically correct, are (excepting for the smallest sizes) too large for sewers in London. It is extremely violent rains alone that produce a depth of two inches per hour, and such rains occur only once in four or five years, if so much. I am of opinion that it is unnecessary to proportion the size of the sewers to meet an extraordinary occurrence that may probably happen only once in so many years. My reason for not fearing any serious damage from an excess of rain at remote intervals, being provided for in surface-channels, excepting perhaps in situations peculiarly liable to inundation, (for instance, at the foot of a long or steep declivity, or where the waters may from any cause be suddenly congregated at one focus,) is that I have observed, that in towns entirely destitute of underground drains, no such inconvenience is felt as would justify the formation of enormously large sewers, or the expenditure of large sums of money to provide against it."

The evidence of Mr. Roe, late chief Surveyor to the Metropolitan Commission, and previously to the Holborn and Finsbury Sewers, will be deemed most valuable, if not conclusive on this subject, both on account of his long experience, his straightforwardness, and unbiassed judgment; he was also the first to pay attention to the subject, and introduced many improvements, before it had become the topic of general consideration. In his evidence before the Sanitary Commission, he states as the result of his experience, that a cylindrical sewer, 48 inches in diameter, with a fall of 1 in 240, is sufficient to drain 100 acres of town-area, allowing for a fall of rain unusually large. Also that in a street 924 feet in length, containing 93 houses on an area of 6 acres, 1 rood, 8 poles, a fall of rain 2 inches in depth, producing 346 cubic feet of water per minute, would require a sewer of 2.44 feet capacity, with an inclination of 1 in 480. Allowing further for a supply of water of 75 gallons per day to each house, he would add to the capacity of the sewer .16 of a foot, making a total of 2.6 feet. With respect to uncovered land, he gives as the result of five months' observation, that the greatest amount that was found to reach the invert from a fall of rain of $\frac{1}{2}$-inch in the hour, averaged 3 cubic feet per acre per minute at the period of the greatest flow, and that that period was generally from the greatest to one hour after the heaviest portion of the rain had fallen.

Mr. Roe's observations on the flow of water in the Fleet Sewer are of great practical value. This sewer, at its outlet into the city, is 12 feet high by 12 feet wide, with a superficial area of 120 feet; it receives the discharge of 60 sewers, the total sectional area of which amounts to about 550 feet, and its inclination varies from 1 inch in 100 feet to 1 inch in 2 feet, while some parts are on a level. The area drained by it consists of 1,181 acres of town-area, and 2,656 acres of rural district. During the unusually heavy thunder-storm which occurred on August 1, 1846, the area of flow at this part of the sewer measured 106 feet; in a heavy thunder-storm in July, 1844, the sectional area of flow was 79 feet, and on an extraordinary thaw, after fall of snow in 1841, the area occupied was 54 feet, while the ordinary flow does not cover an area of 10 feet.

The following table, made under the directions of the same gentleman, are from gaugings of several sewers under his charge, and will give a fair notion of the true state of the case:

Table of Gauging of Sewers.

Area drained.	No. of Houses.	Capacity.	Run of Water.			Area occupied.	During greatest rain in 1846, area occupied.	Distance from the Thames.	Height above Thames high-water mark.	Inclination.
			Average common run.	Area occupied.	When water let on from pipes.					
Acres.		Feet.	Inches.	Feet.	Inches.	Feet.	Feet.	Chains.	Feet.	
110	..	13	3	..	..	..	13.00	120	36	$\frac{1}{2}$ Inch in 10 feet, a main line.
5	100	9.0	$1\frac{1}{2}$	0.08	2	0.13	2.50	150	47.0	3 Inches in 50 feet, collateral Sewer
2.70	69	7.65	$\frac{3}{4}$	0.024	$1\frac{1}{4}$	0.06	2.10	166	52.0	
5.15	104	9.65	..	..	$1\frac{3}{4}$	0.11	2.70	145	47.0	5 Inches in 100 feet.
1.09	49	9.09	..	..	$2\frac{1}{2}$	0.33	1.43	265	120.0	
0.25	32	..	..	..	1	0.04	0.33	157	110.0	
1.36	41	7.65	..	..	$2\frac{1}{4}$	0.23	1.40	151	46.0	
2.16	50	7.65	..	..	1	0.034	1.13	160	51.0	
4.16	120	9.65	..	..	3	0.23	4.17	140	49.0	2 Inches in 100 feet, current impeded by height of water in outlet Sewer.
0.25	16	9.09	..	..	$\frac{3}{4}$	0.03	0.30	155	102.0	
19.10	482	9.09	3	0.23	..	..	6.33	140	50.0	$2\frac{1}{2}$ Inches in 100 feet, current impeded by height of water in the outlet Sewer.
1.00	22	7.65	$\frac{3}{4}$	0.03	..	..	1.13	147	47.0	
1.36	37	..	..	0.05	..	..	1.25	149	47.0	
1.08	31	..	..	0.04	..	..	1.20	151	46.0	
3.42	65	3.14	..	0.09	..	..	1.60	180	118.0	12 Inches in 100 feet.
0.84	40	1.22	..	0.17	..	..	1.22	92	48.0	$5\frac{1}{2}$ Inches in 100 feet.
					Engine waste water.					

In opposition to this evidence, we have the authority of such names as Walker, Cubitt, and Brunel, names which may not be passed by unnoticed, although with the previous statements before us, it seems somewhat difficult to coincide with their views. While, however, we pay due deference to gentlemen of such high standing in their profession, we must not forget that such men as Mr. Roe have probably had the greater experience in this particular class of works. Let us attempt to simplify the question as much as possible.

The objections raised against the old system are, 1st, that they are unnecessarily expensive—2ndly, that they are inefficient Their great expense arises from their size, therefore

we have to show that their size is unnecessarily large. That they are larger than required for the ordinary drainage cannot, we imagine, be a matter of question, after the result of the above observations and experiments have been made known; nor can we attempt to disprove the unvarying evidence on this point, given by persons practically acquainted with the subject; the table of gaugings by Mr. Roe seems to decide this question, for during the extraordinary storm, in 1846, we find that by far the majority of the examples were not full on that occasion, nor, indeed, nearly so. Out of 16 examples only two were filled on this occasion, one of which was a main line of 13-feet capacity, draining an area of 110 acres, and the other a 15-inch drain, relieving an area of 0.84 acres. During the experiment in the Earl-street sewer, which happened in a wet season of the year, a 15″ pipe was found more than sufficient for the drainage of 44 acres of covered ground, with only one exception, which occurred during a heavy storm, when the discharge amounted to above 300 cubic feet per minute. In the experiments in Upper George-street, during a continuance of 96 hours' rain, the 12-inch pipe was never observed to be more than half full; but on one occasion, during a violent storm, the water rose 18 inches above the pipe; this state of things, however, lasted but a short time. The area drained by the Upper George-street sewer was also 44 acres.

Now, putting aside for the present the question as to whether the pipes used in the above experiments were of sufficient capacity, Mr. Roe's experiments, which give, we think we may say, the very greatest amount of discharge which can ever take place, are decisive thus far—that by far the majority of existing sewers are very much larger than can at any time be necessary; and with respect to the exceptional two, it remains a question, whether under an improved system of drainage they would ever have been put to such a test, but under the old system, when, occasionally, a sewer got smaller towards its outlet, the levels were ill-arranged and defective, &c., it is not to be wondered at, that sometimes one sewer had to perform more than its fair share of work, whilst others were almost inactive; if the sewage had been more equally distributed, no one sewer would have been so much overcharged.

Taking then the maximum quantity ever discharged, as the rule to guide us in fixing the proper dimensions of sewers, we find that the old system is too capacious; but beyond this it is questionable whether it is necessary or advisable to provide for such extraordinary flow, and this question becomes of more importance, if it can be proved that extra capacity is detrimental to the efficient discharge of sewage matters. In this state of the case, the real matter at issue is, whether it be preferable to be subject to a constant inconvenience, or a temporary and problematical one. Some say we must provide for all emergencies; others would rather run the risk. We are inclined towards the latter opinion. But there remains another argument in favour of large sewers, and that is, that they admit the passage of a man, for the purpose of inspection and periodical cleansing, which the advocates of the old system deem to be necessary; if, however, it can be proved that smaller sewers will keep themselves free from deposit by the extra velocity and scour of the water, this objection will be removed. Again, this objection will not hold good against the substitution of very small pipes for those sewers which, although much larger than requisite for the ordinary flow, cannot conveniently be entered for this purpose; for if the work causes great discomfort to the labourer, it is certain that it will not be performed efficiently, if, indeed, it be performed at all; we should imagine that sewers less than 4 feet in height, are not inspected much more frequently than a 15-inch pipe would be.

We have now to consider whether drainage may be more efficiently discharged by a small than a large sewer. The small quantity of water ordinarily passing through the large existing sewers, is allowed, on all hands, to be very sluggish in its movement; and that a deposit of solid matter is always going on, and that to a considerable extent, is evident from the fact, that large quantities of solid matter are obliged to be periodically removed by flushing or hand-labour, and in several cases when old drains have been opened, they have been found to be almost choked up by such accumulations. It is certain, therefore, that large sewers do not of themselves efficiently remove the refuse matters. This defect was observed some years since by Mr. Roe, and the cause being determined upon, it was attempted to remedy it by reducing the width of the invert of the sewer, and thus narrow and deepen the channel for the water, thereby producing less frictional area, a greater depth of water, and consequently a greater velocity and improved scour. This practice was found to succeed, and was afterwards adopted in other localities. It may be noted in passing, that where much deposit has taken place, it is observed that the stream forms for itself a sort of gut or narrow channel, thus giving visible evi dence of the requirements of nature in this particular.

As the question relating to the velocity and scour of a body of water in various-sized channels was of considerable importance in determining upon a system of drainage, a series of experiments upon the flow of water through various-sized pipes was made, under the direction of the Metropolitan Commission; and amongst the results given, we find that a 3-inch glazed stone-ware pipe, 50 feet in length, with an inclination of 1 in 120, and being fully charged at the head, will discharge 100 gallons of sewage water in 3 minutes; and that a 4-inch pipe under precisely similar circumstances, will discharge 200 gallons in the same time; and further, that such a flow is sufficient to remove any, and even more than ordinary and usual semi-fluid deposit, such as is usually found in house-drains. A mixture of sand with water, in proportion of from $\frac{1}{16}$ to $\frac{1}{40}$ the volume of water, was also removed. Also that the hydraulic mean pipe of a 3, 4, 6, and 9 inch pipe, when half full, is respectively .749, 1.00, 1.5 and 2.18 inches, and that the fractional line, under the same circumstances, would be 4.71, 6.28, 9.42, and 14.13 inches respectively. Further, that 1 gallon of water through a 3-inch pipe, moved 1 lb.; through a 4-inch pipe, 3 lb.; and through a 6-inch pipe, $\frac{1}{2}$ lb.; and that 3 gallons of water will carry off 1 lb. of solid fæces through a 6-inch pipe with a fall of 1 in 10; but to make these results of use, we ought to be acquainted both with the fall and velocity. Another statement is this: if 81 seconds suffice for the discharge of 50 cubic feet of clean water, 84 will suffice when $\frac{1}{40}$ of solid matter is added, and 91 seconds when the solid matter amounts to $\frac{1}{16}$.

Such results are generally in favour of the small pipes, but it is to be regretted that the experiments were not carried on on a more extensive scale, for they afford little information respecting the larger kinds of pipes. It will be generally allowed, however, that a concentrated body of water will move with greater velocity than the same amount where spread over a large surface, the resistance offered by friction will be less effective in retarding its progress, and the greater depth afforded by narrowing the channel will tend to improve the scour. The scour will depend both upon the depth and velocity of the stream, and will therefore in both ways be more efficient in a contracted channel. On these two properties, depend the efficiency of the drain; for if the velocity be greater, the discharge will also be greater, and the power to keep the sewer free from deposit will increase in like

manner; for, in the first place, there will be less tendency to deposit; and in the second, when a deposit takes place, it will be more readily removed. This is both reasonable in theory, and has been proved in practice, for the evidence of Mr. Lovick and others, who have had opportunity of examining the state of small pipes after they have been in use some time, goes to prove that they keep themselves almost perfectly free from deposit. It will be perceived by the following table, prepared from the experiments made in the Earl-street sewer, that the quantity of solid matter in suspension in sewage-water, bears but a small proportion to the liquid, and it is therefore probable, that with a fair velocity of flow there would be but little tendency to deposit.

TABLES OF SOLID MATTER IN SUSPENSION IN THE FLOW.

No. 1.—*On the Extra Water-Days.*

Quality of flow analyzed, and period when taken.	Solid matter in one Imperial Gallon.			Proportions.	
	Soluble Grains.	Insoluble Grains.	Soluble & Insoluble Grains.	Soluble to Insoluble.	Soluble & Insoluble to Liquid.
Greatest taken, 5½ P. M.	33	19	52	2 to 1	1 to 1346
Mean of 2 analyses, taken at 12 A. M.	119	46	165	2½ to 1	424
Mean of 2 analyses, taken at 8½ and 10½ A. M.	119	37	156	3¼ to 1	448
Least taken at 12 P. M.	111	11	122	10 to 1	574
Total	382	113	495		
Averages	96	28	124	3½ to 1	564
When water first laid on, or at commencement of overflow from cisterns	80	192	272	1 to 2½	257

No. 2.—*On Ordinary Days.*

Quality of flow analyzed, and period when taken.	Solid matter in one Imperial Gallon.			Proportions.	
	Soluble Grains.	Insoluble Grains.	Soluble & Insoluble Grains.	Soluble to Insoluble.	Soluble & Insoluble to Liquid.
Greatest mean of two analyses taken at 12 A. M.	114	34	148	3¼ to 1	1 to 473
Mean taken at 8½ A. M.	154	71	225	2 to 1	311
Least taken at 12 P. M.	114	14	128	8 to 1	546
Total	382	119	501		
Averages	127	40	167	3¼ to 1	419

The principal objections against the use of small-pipe sewers are: 1st. That if any obstruction occur in the pipe, so as to cause accumulation of deposit, the pipe rapidly becomes completely stopped up, whereas, in the larger sewers, even though obstructions may occur, they will not entirely stop the flow, or at least the accumulation must proceed for a considerable period ere the entire area be filled up. 2nd. That if such stoppage take place, there is no means of ready access to the sewer to examine it, and that the road will probably have to be broken up in several places ere the drainage be repaired; and even then it is almost impracticable to reinstate the pipes in the same conditions as when first laid down. 3rd. That owing to the nicety required in laying the pipes, an uniform inclination is not easily preserved, nor is there any satisfactory means of knowing when the invert is perfectly smooth; that if the pipes be defective in form, or imperfectly laid, or if the cement with which the joints are made be allowed to project within the pipe above the general surface, an obstacle is at once offered to the flow, which is not unlikely to cause deposit, and thereby a stoppage in the pipe.

Now, in the case of the first objection, it does appear feasible, that a small pipe would be more rapidly filled up than a large sewer, but yet there are some grounds for supposing the contrary to be the case; for as the water-way becomes contracted, so also does the scour of the stream increase; and moreover, the stream being ponded back, we shall have a full head of water to increase the power of the flow, so that it would appear, that unless the matter causing the obstruction be extremely difficult of removal, the water-way is not likely to be entirely closed up.

The second objection must be allowed to possess considerable weight; in case of stoppage, it would, in truth, be a matter of great difficulty and inconvenience to remedy the accident; yet, at the same time, we must not forget, that even in brick sewers, if they be of the smaller class, there is no very ready means of access; and moreover, they are more likely to encourage deposit; we are inclined to think, that if pipe-sewers be carefully laid, and fairly used, they would not be likely to silt up. The objection to breaking up the roads, for the purpose of discovering the stoppage, can scarcely be overrated; and it is also true, that it is very difficult to relay the pipes in their former position, unless indeed they be made with half-socket joints, or be made of two semi-cylindrical pipes one laid over the other.

The nicety required in laying the pipes, and the difficulty and uncertainty attending the practice, is certainly objectionable; there is no means of seeing the interior of the pipe, to observe how the work is performed, and it is not unreasonable to suppose, that the cement at the joints, by the carelessness of the workmen, is sometimes left to form a projecting ridge above the surface of the invert. To prevent any obstructions at the joints, it has been proposed to make the pipes of a slightly conical form, inserting the smaller end of the first into the large end of the succeeding pipe; this, however, seems rather an awkward method of meeting the difficulty; and we are inclined to think, that a better method would be, to make the pipes in two pieces, as suggested above, first laying the inverts and securing their accuracy, and then covering them over with the upper half; but neither is this plan without objections.

As regards the separation of house from surface drainage, so long as the latter bears so small a proportion to the former, we do not think it advisable to form a separate system for each; but in cases where the proportion of surface-water is increased, and the house-drainage tolerably uniform, it may possibly be advisable to separate them, if the sewage be intended for dry manure; otherwise, we should scarcely deem it expedient: with reference to the size of sewers, we do not think it necessary to provide for extraordinary storms; we would rather have the advantage of a good general drainage, and the occasional and temporary inconvenience caused by a heavy storm, than be safe from the latter, with the constant inconvenience of imperfect drainage. Generally speaking, we should advise a system of pipe-sewage, somewhat larger in proportion to the area drained, than that observed in those laid down for experiment in Earl-street; for besides, that on such occasions the pipes are likely to be more carefully laid than in ordinary cases, we find that on one occasion during that month, the water reached a height of 9 inches above the head of the pipe. We would allow for such storms as are likely to occur once a month, but not such as occur only once in three or

four years. On this one occasion, at Earl-street, the discharge was above 300 cubic feet per minute, and as a similar overflow is recorded in Upper George-street, we may reckon that such discharges are not unfrequent during the rainy season: we must not forget, however, that the pipes in these instances were connected with an imperfect system of collateral drains; and that under a perfect system, the surface-water would have been carried off more rapidly, and there would not have been so great an accumulation at this point. A little experience of the working of a perfect scheme of this description, would readily determine the requisite sizes.

In main lines of sewer, and where they pass under main roads, we should recommend the construction of brick sewers of such size as would be sufficient for the passage of a man, and for room to work in when requisite. In these we would lay not only a pipe-sewer of sufficient capacity for the usual run of water, but also the gas and water-mains, where practicable, in order to obviate any necessity for breaking up the roadway on occasion of repairing, &c. We are convinced that this arrangement is of considerable importance, where the roads have to sustain much traffic, for it is impossible to maintain good roads while they are constantly being broken up by gas and water companies. The expense of this system, as far as regards the sewers, would not be much greater than the present, and there can be no doubt but that the management of the roadways would be much more economical. Under such circumstances, it would be worth while to construct a good solid roadway, which, though a little more expensive in the first outlay, would in the end prove much more economical, not only as regards the repair, but also as requiring a less amount of tractive power, and doing less damage to the vehicles passing over it. It is very advisable, that all subterranean works should be treated of together as separate portions of one system. The pipe-sewers should be laid in the invert, and might be so arranged as to allow of an overflow into the large sewer, when requisite; or the water might be poured back, for the purpose of flushing when deemed advisable. Access would be obtained into the sewer, for the purpose of inspecting and repairing the various pipes by side-entrances, as at present; and the sewer ventilated by shafts in the roadways, without detriment to public health, the pipes which convey the sewage being impermeable. The only difficulty which limits the application of this system to main roads and sewers, is its expense; were it not for this, it might be adopted in every street with much advantage.

Many forms of large sewers have been adopted, but that which appears to be best adapted for the purpose, is the egg-shaped, which was introduced by Mr. Roe; the older forms having mostly a semicircular crown, with upright side-walls, and a semicircular or flat segmental invert. The main improvement effected by the egg-shaped sewers, consisted in narrowing the invert, thereby contracting the lower part of the channel, and increasing the depth of flow, by which means the velocity and scour was much improved; the same quantity of water which moved but sluggishly when spread over the wide surface of a flat invert, being now concentrated in a narrow channel, was made to move with accelerated flow; in short, this alteration had a similar effect to that produced by the employment of small pipe-sewers. Another advantage obtained by this form, was the attainment of greater height with a given area, which enabled men to pass through them with greater facility; it must be confessed though, that the narrow invert is rather inconvenient to walk upon. The shape, moreover, is economical, and based on sound principles as regards construction.

Many proportions, and many methods of describing the egg-shape, have been observed at different places, some being constructed with a semicircular top, flat segmental sides, and a sharp segmental invert; the curves of the sides and invert varying according to varying proportions of height and width, and other circumstances. Others are constructed with six centres, the upper part being described with two radii, instead of being semicircular. Of all these varieties, however, the most eligible is thus described:—Let the height of the sewer be to the width as 3 to 2; then having described a semicircular crown with radius 1, with radius 3, equal to the height, and with the centre on the springing-line, describe a segment touching the semicircle already described; for the invert, with a radius $\frac{1}{2}$ or $\frac{1}{6}$ of the entire height, describe a circle which will be found to touch the segments just described. This form is generally applicable, and has the advantage of being drawn to certain proportions.

The above are the most usual forms for sewers, but occasionally the levels will not allow sufficient height for them beneath the roadway; and, in such cases, it is necessary for the purpose of obtaining sufficient capacity, to construct them of a cylindrical or elliptical form; but even then, the same end may frequently be obtained by placing two or more egg-shaped sewers side by side. Where there is a large and constant flow of water, cylindrical sewers are not objectionable.

The above sewers, if not more than 4 feet in height, and if in good building strata, may be constructed of half-brick work, but in other cases require to be a whole brick thick, unless the sewer be very small. They are constructed mainly of stock-bricks in mortar, the invert or lower portion only being laid in cement; the inverts are usually formed in blocks in cement before they are finally laid in the sewer; the invert consisting of three or more blocks, according to its dimensions. Sometimes blue vitrified bricks are used for the invert; they are very hard and durable, but do not adhere well to the cement. It has been proposed to construct sewers with radiated bricks, and they probably might be used with advantage where the curve is sharp: the joints of common bricks are very open in such cases. Radiated hollow bricks have also been suggested, and, if moderately cheap, they might doubtless be employed successfully.

The pipe-sewers, as at present made, are of a cylindrical form; they are constructed in lengths of 2 or 3 feet, and have a socket at one end for the adjoining pipe to fit into; sometimes, however, they are made with half a socket on either pipe, and this is of advantage in facilitating their removal, if at any time they be required to be taken up. With the whole sockets, it is difficult to take them up without breaking them, and it is almost impracticable to replace them correctly after removal.

If whole-socket pipes be generally used, we should advise the occasional adoption of half-sockets, so that in case of stoppage, or other accident, they may admit of easy removal and replacement, without either destroying the pipes or disturbing the adjoining ones. Cylindrical pipes are made from 3 to 2 feet in diameter. It has been suggested, that such pipes should be made of the egg-shape, rather than cylindrical; but it must be borne in mind, that the contraction of the invert is not of so much consequence in a small pipe, where there is likely, at all times, to be a large current compared with the capacity of the pipe; and if the pipe be generally full, we know that the circumference of a circle contains a larger area than the same extension of boundary-line arranged in any other form; therefore, if a cylindrical pipe be full, there is less frictional surface than in any other kind of pipe of the same capacity. As, however, in present practice, the flow of water varies to a great extent at different times, it

might not be unadvisable to adopt the egg-shape, supposing that they can be manufactured with the same accuracy, and at no higher cost. If they be adopted, we should advise their being made in two pieces, the lower one forming the invert, and the upper the semicircular crown; a flange, or socket, might be formed at the edge of the bottom-piece to receive the top, and make a correct joint; the same practice might be adopted in cylindrical pipes of a large size. The advantages attaching to this method are, that the inverts can be laid with great nicety, a matter of considerable importance, and are open to inspection after they are laid, so as to admit of opportunity of testing their accuracy; the objections against the whole pipes, on this head, are of considerable weight. Another advantage is, that the top-half can be taken off at any time for examination or inspection of the pipes, without disturbing the invert, or interfering with the flow.

These pipes are manufactured of stoneware, and various kinds of clay, glazed and unglazed, some being glazed on the interior, and others on both surfaces; the stoneware, glazed on both sides, are most frequently adopted, and are found to answer best; but there is a process of manufacture which produces unglazed pipes equally efficient as the glazed stoneware. The peculiarity of this process consists in submitting the pipe, when half-dry, to an extreme pressure between two polished iron surfaces, whereby a density of substance, and truth of form, is attained, which is equivalent in practice to the best glaze, so far, at least, as the flow of water is concerned. Pipes of the above materials and manufacture have a great advantage over brick-sewers, on account of the comparative smoothness and evenness of surface, which offers very little or no resistance to the current; the amount of frictional resistance being naturally greater over the rough surface of the brick work. In the following table will be found the result of some experiments, for the purpose of determining the advantage gained, in this respect, by glazed pipes:—

Table of Comparative Time of Run of Water through Brick Drains and Glazed Pipes.

Inclination.	Depth of water.	Time through Glazed Pipes.	Time through Brick Drain.
	Inches.		
Level.....	5	38	50
2 Inches in 50 feet	4½	16½	25
3¾ ditto	5½	19	27
1¼ ditto	3	18	26
½ ditto	3½	25	36
3¼ ditto	4	15	22
1¾ ditto	6	13½	21½

The rate of inclination is a matter which requires some consideration in laying out a system of drainage; the greater the fall, of course the greater the velocity, and, in consequence, the more rapid the discharge; the scour is also proportionately greater. It will thus be seen, that the efficiency of sewers depends a great deal upon their rate of fall towards the outlet; this, however, will depend mainly upon the nature of the locality to be drained. Supposing there exists a certain fall from the highest point to be drained to the outlet, it will be well to see how it can be laid out or expended to the greatest advantage:—the rule is this, give the greatest rate to the house-drains; the next greatest, to the pipes with which they are immediately connected; and so on, diminishing the rate gradually as you get towards the outlet. The reason for this is obvious; for, in the first place, your main object is to remove the sewers from immediate proximity to the houses, so that perfect drainage is of less consequence at a distance than it is in the houses themselves. But beyond this, there is another more important object in this arrangement, for as the body of water is less in the sewers or drains more remote from the outlet, it is more likely to be sluggish in its movements than where there is a large volume of water, and this tendency to sluggishness is overcome by an increased rate of inclination, so that the want of velocity caused by the small body of water in the smaller sewers is compensated by the extra fall, and thus the flow in all cases is rendered equal, or nearly so. In the larger sewers, where the water is collected from the tributaries, the mass of water is sufficient to preserve a good velocity with even a small inclination. The rate will depend, as we said before, upon the nature of the ground; but, as a general rule, it is advisable that the fall in main pipes should not be less than 1 in 240, and in main-sewers not below 1 in 1,000. It has been deduced from experiments, that no proportionate advantage is gained by a fall of more than 1 in 60. The requisite size of the pipes is dependent, in a great measure, upon their fall, for as the velocity is increased in proportion thereto, so is also the rate of discharge, and therefore the greater the fall, the less will be the sectional area required for the sewers.

Where one sewer discharges its contents into another, the junction should be effected by a curve, drawn tangent to the directions of both sewers, so that the direction of the stream may be changed in as easy a manner as possible, and may not experience any shock either in leaving the smaller or entering the larger sewer. It was formerly the practice to make the junctions rectangular, but by this method the stream from the tributaries, crossing that of the main at right angles, had a tendency to change its direction, the amount of change depending on the comparative force of the two streams; in any case, however, the flow in the main stream was impeded, eddies caused, and deposit thereby accumulated. If, on the contrary, the two streams be tangential at the point of junction, little or no impediment will take place, as they have both a tendency to move in the same direction. It is advisable, that the curve be struck with as large a radius as practicable. In the pipe-sewers, junction-pipes are made for the purpose, in which the junction-curve is commenced on the main-pipe, so that we have a straight pipe, and a portion of a curved one, in the same length; the pipes are made to suit different circumstances, some with one, others with two junctions, and these of various sizes as required. With respect to the time occupied by the passage of water through different junctions, the following results have been arrived at by Mr. Roe, after various experiments:—

Time occupied by the passage of equal quantities of water through similar lengths, and with the same inclination.

Along a straight line—90 seconds.

With true curve—100 seconds.

With turn at right angles—140 seconds.

It is to be observed with reference to junctions, that it is not necessary to increase the capacity of the main line at every junction with a tributary, or that the area of the main should be equal to the area of all the junctions. The reason of this apparent inconsistency is, that although a pipe be full at its head, it will be found to be not nearly full at its outlet, and this is caused by the increased velocity of the particles of water acquired by running down an inclined plane. At a little distance from the head, therefore, some portion of the sectional area of the pipe will be vacant, sufficient to afford room for the discharge of a tributary, which will in its turn add to the velocity of the main stream, and leave space for a second tributary at a joint lower down. There is, of course, a limit to the addition of tributaries, for in time the areas of the main will be comparatively full, and will dam

up the water in the junctions; the extent to which the principle can be carried, is to be determined by practice; it will depend to some extent on the fall of the main line.

Where sewers are constructed with the intention of being entered for inspection, it is necessary that they should be properly ventilated; otherwise, the noxious gases generated by the sewage, would forbid entrance, except at considerable risk of life: fatal accidents have occurred, for want of such precaution. The usual plan for effecting this, is to construct a long, narrow, and tapering shaft from the crown of the sewer to the roadway; but this practice is objectionable, on account of the gases vitiating the atmosphere, and thus encouraging disease; and it does appear somewhat inconsistent, that while gullies are trapped to prevent the ascent of the effluvia, other shafts are constructed for the purpose of effecting it. It is true, there is some advantage gained in ventilating by the vertical shaft, but not sufficient, it may be imagined, to counterbalance the inconsistency. Several methods have been attempted, to obviate this difficulty: amongst which may be mentioned, the connection of the ventilator with the rain-water pipes of the houses, and extending them a considerable height above the houses; the passage of the air through a furnace; the ventilation by steam-jet, &c.; each of which plans have been more or less successful. If we adopt the pipe-sewers, all difficulty on this score is at once obviated, for the pipes themselves are impermeable, and if the gullies and house-drains be properly trapped with syphons or flaps, there will be little danger of the escape of noxious vapours; and it must be remembered, that in this case, the sewers themselves are not required to be ventilated, seeing that they do not admit of passage by a man. That they are ventilated, however, to a certain extent, is very probable; for it is well known, that the rapid motion of a stream of water will produce a sensible current of air, and in proportion as the velocity of flow is greater in small than in large sewers, so will their ventilation be more completely effected: besides this, as the deposit is likely to be less, there will be less need of ventilation.

In large sewers, it is necessary that there should be ready means of access to them, and this is best provided for by side-entrances, which consist of vertical shafts descended by iron ladders or step-irons, and covered with cast-iron flaps. These shafts are placed at any convenient spot, at the side of the sewer, generally in the footpath, where the sewer is in the middle of the road, and from the bottom of the shaft an arched passage is carried with a slight inclination under the roadway into the sewer, the lowest level of the bottom being from 6 to 18 inches above the invert.

Gullies require to be constructed at certain intervals, to carry off the surface-water from the roads. The water is carried by gratings in the channel of the road into a cesspool or well, and thence by an overflow-pipe with syphon trap into the sewer. The grating should be made to open, or other access afforded to the cesspool, in order to remove the deposit when requisite.

Having treated upon the subject of drainage generally, we now come to the consideration of house-drainage, which requires a few remarks. The old system of carrying the house-drainage into the main-lines, consisted simply in laying down a drain from each house, connected at the one end with the sinks, water-closets, &c.; and at the other with the main sewer, which ran in the centre of the road. Amongst the recent improvements, a new plan has been adopted, by which the drainage of the house is conducted into a pipe at the back of the premises, and by it into a main sewer; this is termed *back-drainage;* and the old system, *front-drainage;* for whereas in the former case, the sewage is collected at the back, in the latter it is collected at the front of the houses. The system of back-drainage is certainly in many respects an improvement upon the old, but it is not so universally applicable as some persons would lead us to believe; it provides a convenient variation, but not an extensive substitute. One great improvement is effected by carrying the drainage at once away from the premises, instead of its running under them, as before. The objections to the old system in this respect, are, the passage of the drains under the houses, whereby, if not perfectly constructed, the effluvia is likely to be spread all over the interior; and the inconvenience which is thereby occasioned in case of stoppage, or other necessary examination or repair which involves the removal of floors, &c., and the opening of drains in the house; matters not only inconvenient, but sometimes dangerous, on account of the escape of effluvia. In some cases, where the old brick drains have been employed, and, as is not unfrequently the case, improperly constructed, the drainage has been allowed to escape through crevices in the brick-work, and saturate the foundations of the premises; this is frequently the cause of damp basements, and of unpleasant and noxious odours in the lower part of the house. A further objection exists in the frequent apertures required to be made into the main sewer for the insertion of the house-drains, and the many interruptions which are occasioned in the flow of the sewage in the main sewer, by the discharge of so great a number of house-drains.

These objections are obviated almost entirely by the new system; the drains, instead of being carried through the house, are at once removed from it, and the dangers and inconvenience attending the old practice entirely done away with. Such at least is the case in by far the majority of instances: occasionally, where the position of water-closets in front of the house requires the drains to be brought through the house to the back, the employment of the new system would not be so advantageous; the carrying of drains from sinks through the house, is not so objectionable. The large sewers will not be interfered with, except at distant intervals, for the insertion of the main back-drain, discharging the sewage of a block of several houses. There are several other advantages attending the new system, amongst which may be mentioned the following:—The flow of sewage is very considerably improved by its concentration into one drain, instead of being spread over many; the frictional surface is also much reduced. In the old system, the occasional flow of water from each house was so inconsiderable as to produce a mere dribble, which flowed sluggishly, and deposited its solid matters in abundance, under the very dwellings; it was but a small portion that eventually reached, and was discharged into the sewer; whereas, where the back-drainage is adopted, the water is discharged almost immediately into the main back-drain, and the collection of the sewage of all the houses therein produces a considerable volume, sufficient at all times to keep up a moderate flow into the main sewer, and thus prevent deposit; if, however, deposit should occur, it is less objectionable than where it takes place under the house. There is a fair objection to this system when stoppage does occur, for the stoppage in one place will occasion the same in every house which happens to be situate between the stoppage and the first inlet; under the old system, this would not take place. In the separate system, each occupier is subject to the inconvenience occasioned only by his own negligence or carelessness, whereas in the combined system he is, to a certain extent, at the mercy of his neighbours; when, however, we take into consideration the improved flow in the main back-drain, and the less probability of stoppage, this objection will not have so great weight.

It will also be frequently found, that a considerable length of drain is saved by adopting the combined system, and where this is the case, back-drainage is decidedly preferable; for not only is the expense lessened, but the fall is likewise improved, and the contents are more rapidly and more efficiently discharged. Where length of drain can be effected by back-drainage, there can be no question as to its adoption; yet there are some instances in which this is not the case, but the contrary rather; and under such circumstances, considerable discretion will be required in selecting that system which shall be most efficacious.

The drains employed in carrying the sewage from the houses, need not be more than four inches in diameter, of the same material and descriptions as those above recommended for sewers; 6 or 9-inch pipes will generally be found of sufficient capacity for the main back-drains, but of course this will depend upon the number of houses drained into them. These should be trapped at their entrance into the sewers, to prevent the effluvia rising through them from the sewer into the houses. Sinks, water-closets, &c., should also be trapped at the inlets.

We are now arrived at the close of this article; and we are sure that the increasing importance of the subject will excuse the length to which it has been carried.

SEXAGESIMAL, (from the Latin,) the division of a line, first into 60, then each of the parts into 60, and each of these again into 60, and so on, as long as division can be made.

This division is principally employed in dividing the circumference of a circle, and was much used in ancient astronomy. The French have adopted the centesimal division, which is far more convenient for calculation.

SEXAGON, or Hexagon, a six-sided figure.

SHADOWING, in drawing, the art of representing the various degrees of light and shade by means of a dark fluid, or liquid.

The paper intended to be drawn upon, having its rough edges cut off, ought to be wetted, or uniformly moistened, and pasted round its four edges upon a board, observing, in doing this, that no part of the paper ought to be suffered to dry before the edges that are pasted, as the paper will begin to shrink; and, consequently, by its motion towards the centre, will loosen the edges: as soon, therefore, as the middle part appears dry before the edges, it ought to be moistened again with a sponge, and the sponging should be repeated as often as may be found necessary; and, when the paper becomes dry, it will be perfectly flat, and fit for use.

In order to lessen this trouble, some have drawing-boards framed so as to include a panel, which is let into a rebate, on the inner edge of the frame, and fastened, by means of bars, upon the back of the board.

The paper being wetted on the side intended to be drawn upon, the dry side is laid upon the face of the panel, now out of the frame, so that the edges of the paper project alike on all sides, over the edges of the panel; then laying hold of the paper by the edges out of the panel, place it over the aperture in the frame, with the underside reversed, and press it in; after which, bolt the panel to the frame by means of the bars, and the edges of the paper being inserted in the seam, or joint, between the edges of the panel and the adjacent edges of the frame, will prevent the paper, as it contracts in drying, from returning towards the centre, and, when dry, it will be flat and extended; but this method can only be practised in small drawings. The former must, therefore, be considered as the general plan of fixing the paper.

The fluid commonly used in architectural drawings is Indian ink dissolved or mixed in water. The method of doing it is this: fill a small cup with as much water as may be necessary for the quantity of ink intended to be made; then rub the ink upon the tip of the fore-finger, wetted in water, and wash it off in the cup: when the water becomes sufficiently dark, it will be fit for use. This method is, however, too tedious for general use, the more frequent practice is to rub it up as other colours. The stick of ink should be rubbed quite dry, otherwise it will be apt to fall into pieces, and become unfit for use. The liquid thus made is called *ink* or *colour*.

The next thing to be done is to outline the drawing.

Straight lines are drawn with a steel pen, circles by the compass, and curve lines by hand, with camel or sable hair pencils, or with a fine-pointed pen, or with curved ruler and drawing pen.

In drawing very fine lines, the inking-points of the steel pen and compasses ought to be kept very sharp, but not so much as to cut the paper. The outlines being finished, the paper ought to be rubbed clean, and then sponged, or rubbed with a soft brush and water, in order to soften the lines, and to make the paper receive the shadowing more freely. If the paper be even sponged, or brushed, so as to raise the nap in a small degree, it will be the more favourable for producing clear and soft shadows.

In laying the shadowing colour upon the paper, it ought to be spread over the surface uniformly with a camel or sable hair pencil, flowing freely; but not in such quantities as to stand in hollows upon the paper, as, when dry, it becomes cloudy. In making a uniform tint, the first thing to be considered is, the degree of darkness to which the surface is intended to be made. If required to be very light, one tint, or the shade once gone over, will be sufficient; but, if dark, several tints will be necessary. In producing the several degrees of darkness, every tint ought to be nearly dry before the next is laid; the number of repetitions will depend upon the depth of the colour and extension of the surface to be shadowed. It may be observed, that the lightest tint, often repeated, will darken the surface to any degree required. But that too much time may not be dedicated to laying a fine tint, it must also be observed, that the greater the facility with which the tints are laid, the fewer will be required to darken the surface. This facility is to be obtained by sufficient practice.

SHADOWS, *The Doctrine of*, in perspective, is the theory and practice of representing shadows, as projected from a given point at a finite distance, such as a candle; or as projected from the sun, where the distance, though not infinite, is, for the sake of simplicity, considered as such, in order that the rays may be all parallel; or otherwise, for this purpose, the rays may be supposed as proceeding from all points of space in parallel lines.

Definition 1.—A line of shade is the line deprived of light by an opaque point opposed to the luminary.

Definition 2.—A plane of shade is an opaque or dark plane, occasioned by the privation of light from the interposition of a straight line opposed to the luminary; and hence it is evident, that every plane of shade will pass through the luminary.

To find the shadows, upon the surfaces of bodies, occasioned by the privation of the sun's rays.

Proposition I.—*Given the vanishing line of a plane, the vanishing point of the sun's rays, the vanishing point of the seat of a ray on the plane, the representation of a point in space, and the representation of a seat of the point in the plane whose vanishing line is given; to find the representation of the shadow upon the plane of the picture.*

Join the vanishing point of the line to the vanishing point of lines perpendicular to the plane whose vanishing line is given, and the vanishing line of another plane will be obtained, in which is the original of the seat of the point, and the original of the line in projection; and, therefore, the intersection of the vanishing line given of the plane on which the seat of the line required to be drawn, and the vanishing line found, is the vanishing point of the seat of the line. Therefore, draw a straight line through the seat of the point given in projection, to the vanishing point found, and the line thus drawn will be the whole representation of the seat.

This proposition is evident, since the vanishing line of every plane perpendicular to the plane whose vanishing line is given, will pass through the vanishing point of lines perpendicular to that plane; and since the seat of the original line, on the original of the plane given, is formed by a plane passing through the original line perpendicular to the given plane intersecting therewith; therefore the vanishing line of this perpendicular plane will pass through the vanishing point of lines perpendicular to the original of the plane given; but when two points in a vanishing line are given, the whole of the vanishing line is given, being the straight line passing through these points.

A general knowledge of the shadows of lines upon planes in any position ought first to be acquired; but as the relation of lines and planes to the horizon is generally given, it will be necessary to find the relation of these lines and planes to each other; and here it will be proper to observe, that whatever may be the number of planes, the vanishing point of the sun's rays will remain unchangeable, or in the same position in respect of the first vanishing line, and will be common to all the different planes; but every different plane will have its own vanishing point for the seat of the sun's rays in that plane, and that vanishing point will be in the vanishing-line of that plane. As vertical and horizontal planes occur most frequently in practice, these will require particular attention.

Proposition II.—*Given the inclination of a plane to the plane of the picture, both being perpendicular to the original plane, and the seat and inclination of a straight line in the plane of the horizon; to determine the vanishing point of the seat of the line on the vertical plane, and the vanishing point of the line.*

Plate I. *Figure* 1.—Let No. 1, represent the vanishing plane, and No. 2, the plane of the picture. In the vanishing plane, No. 1, let v l be the vanishing line, e the point of sight, or place of the eye, A B the intersection of the original vertical plane, inclined to the plane of the picture in the angle A g l; and let A D be the seat of the line, as given in position, to the horizon: make the angle D A F equal to the inclination of the line to the plane of the horizon; draw D F perpendicular to A D, and D B perpendicular to A B; produce D B to K; make B K equal to D F, and join A K, which is the seat of the line on the vertical plane. Draw e *l* parallel to A B, and draw *l h* perpendicular to v *l*; in v *l* make *l m* equal to *l* e, and make the angle *l m h* equal to B A K; and *h* will be the vanishing point of the seat of the line. Draw e v parallel to D A, and v *i* perpendicular to v *l*; make v *n*, in the vanishing line, equal to v e; make the angle v *n i*, equal to the angle, D A F, which the original line makes with the plane of the horizon; and draw e ⊙ perpendicular to v l, meeting v l in ⊙. In the plane of the picture, No. 2, let v L be the vanishing line answering to v *l*, No. 1: in v L make choice of any convenient point, ⊙, for the centre of the picture: make ⊙ L equal to ⊙ *l*, No. 1, and ⊙ v equal to ⊙ v, No. 1; draw L H and v I perpendicular to v L; then H is the vanishing point of the seat of the line, and I the vanishing-point of the line itself.

The points H and I will be both on the same side of the vanishing line of the horizontal planes.

This problem is the same when the seat and altitude of a ray of the sun are given, with the inclination of a vertical plane to the plane of the picture; to find the vanishing point of a ray of light, and the vanishing point of the seat of the sun's rays.

When the sun is on the same side of the picture with the spectator, the vanishing point of the seat of the rays, and the vanishing point of the rays, will be below the vanishing line, v L; but when on the other side of the picture, the vanishing point of the rays, and the vanishing point of their seat, will be above v L.

Proposition III.—*To find the shadow of a rectangular prism upon the horizon on which it stands, and also upon another rectangular prism; the base of the prism which throws the shadow being in the same horizontal plane with a side of the prism on which the shadow is thrown.*

Figure 2.—Let o be the vanishing-point of the sun's rays, v s the vanishing-line of the horizontal plane on which the two prisms are placed, *a b c d* the base, and *a' b' c' d'* the top of the prism that throws the shadow. Then, because the edges of the prism stand parallel to the picture, they will have no vanishing point but at an infinite distance; thus the line o s, drawn from o, will be parallel to the edges *a a'*, *b b'*, *c c'*, *d d'*, of the erect prism, and will give the vanishing-point, s, of the shadows of *a a'*, *b b'*, *c c'*, *d d'*; therefore, draw *a* s, *d* s, *c* s; and *a'* o, *d'* o, *c'* o, cutting *a* s, *d* s, *c* s, at the points *e*, *f*, *g*; then will *d e f g c* be the shadow on the ground. Let *c* s and *d* s cut the edge of the prism, *o p q r s t u*, at *h* and *i*; draw *i l* and *h k* parallel to o s, cutting the upper edge, *r t*, at *k* and *l*; from the points *k* and *l* draw lines to s, cutting the farther edge, *q s*, at *m* and *n*; then *h k m n l i* will be the shadow upon the recumbent prism, *o p q s t u*.

Proposition IV.—*To find the shadow of a cylinder lying with its convex surface upon a horizontal plane.*

Figure 3.—Let x be one end of the cylinder, Y the other. To find the shadow of the end x upon the horizon, it must be observed, that no line which terminates two surfaces can throw a shadow upon a third, unless one of such two surfaces be in shade. We have, therefore, only to find the shadow of that part of the circumference of the end x, contained between the point of contact on the horizontal plane, and a tangent plane to the surface of the cylinder; and a sufficient number of points will be found by letting fall perpendiculars from as many points in the arc that throws the shadow, to meet the horizontal plane; then find the shadows of the upper extremities of these lines, which will be points in the curve. Or, find the whole ellipsis representing the shadow of the circumference of each end of the cylinder, and draw the line *c g*, to touch these two ellipses; then *d e c g* will be the shadow. To find the shadow of any point, c, in the edge of the end x; draw c d perpendicular to the horizon, meeting the horizon in d; also, draw d o and c s, cutting each other in *c*, then *c* is the shadow of c; in like manner, *e* will be found to be the shadow of e, and so on for as many points as may be necessary.

Proposition V.—*To find the shadow of one cylinder upon another. The cylinder which throws the shadow, and that on which the shadow is thrown, being placed, the former with its end, the latter with its convex surface, upon the same horizontal plane.*

The shadow of the cylinder, which stands upon its end on the horizon, is obtained by finding the shadows of the tops

of as many straight lines on the convex surface as may be thought sufficient for the purpose, which will give the points f, g, e. The shadow of the cylinder, which is placed with its convex surface upon the horizon, is found in *Figure* 3. Let A E and G F be the lines of contact with a tangent plane to the point S, then the lines A E and G F will throw the shadow partly upon the horizon and partly upon the convex surface, z, of the cylinder, which lies on the ground. It is, therefore, only necessary to find the sections of the cylindric surface z, with the two planes of contact, S A E and S G F; for this purpose, produce the plane A G F E, and the end, T, of the recumbent cylinder, till they meet in P Q. This will be readily done as follows: produce G P, and from the vanishing-point, L, of the end T, of the recumbent cylinder, draw the line L a P, through the point a, and also draw P Q perpendicular to the vanishing-line V L; then P Q is the intersection of the plane passing through G F and A E, with the plane T. Let a d' be a vertical diameter from the point of contact, d′, of the end T; draw L d' Q; then, in P Q take any number of intermediate points, R, S; draw R L, S L; also draw lines from S, R, Q, to the vanishing-point of A G and E F, cutting A E at B, C, D; let the lines from R, S, drawn to L, cut the end T at c, b: draw b V and c V; also draw B L and C L, cutting b V, c V at *b* and c; then *b* and c are points in the shadow. In the same manner, points in the other edge will be found, and the shadow completed.

Proposition VI.—*To find the shadow of a building with a break.*

Figure 5.—Let V L be the vanishing-line of the horizon. V the vanishing-point of the horizontal lines represented by *a c* and *b d*, that form the end of the building, also of *e f*, *g h*, which represent the horizontal lines forming the sides of the break. Let the sun be supposed to be in the plane of the picture, or its rays parallel thereto, and let the planes *a b d c* and *e g h f* be in shade; and the plane *e g h f* will throw a shadow upon the plane *a b l k*, as the plane *a b d c* will also upon the horizon. As the sun's rays are parallel to the picture, they will have no vanishing-point, but still the rule will hold in this case also. Through the vanishing-point L, draw L M perpendicular to V L; then L M is the vanishing-line of the plane *a b l k*, on which the shadow is to be thrown; through V draw V M, parallel to the sun's rays, or make the angle L V M equal to the angle which the sun's rays make with the plane of the horizon. Thus M is the vanishing-point of the shadow of all lines vanishing in V, upon the plane *a b l k:* therefore, to find the shadow of the line *h g*, join M *h*, and produce it to *m;* and draw *g m* parallel to M V; then *m* will be the shadow of the point *g*, and *h m* of *h g*. Draw *m n* parallel to *g e*, and *m n* will be the shadow of *g e:* therefore *h m n f* will be the whole shadow of the plane *h g e f*, upon the plane *a b l k*. To find the shadow of the end *a b c d* upon the plane of the horizon: draw *a o* parallel to L V, and *b o* parallel to M V; then *a o* is the shadow of the vertical line A B: join *o* V, and draw *d p* parallel to M V, and *o p* is the shadow of *b d*: join *p* L, and draw *r q* parallel to M V, and *p q* will be the shadow of the line *d r*, not seen: join *s q*, or draw it parallel to L V; then *a o p q s* will be the shadow of the building upon the plane of the horizon.

Many more examples of shadows might be given; but if the principles here shown are understood, the artist will not be at a loss to find the shadow of any right-lined object whatever: for, to find the shadow of an object constituted by planes, and consequently terminated by straight lines, is no more than to find the shadow of those lines. If a circle be given, the circumference may be divided by parallel lines into parts, and the shadows of the points of division may be obtained by finding the shadows of the intercepted lines, and drawing a curve round their extremities. If it were required to find the shadows upon several planes, first find the shadow in the plane on which the object stands, and observe where the shadow meets the next plane; then, having the vanishing-line of this second plane, observe where the vanishing-line of the plane of shade cuts the vanishing-line of this second plane, and the point of intersection will be the vanishing point of the shadow on the second plane.

The principles exhibited in the article Projection, will apply equally to the representation of objects in perspective, particularly where the planes which throw the shadow intersect the plane on which the shadow is to be thrown; for by continuing the line that throws the shadow, and the intersection of the planes, to meet each other, the point where the shadow terminates is found; and therefore, if a point be given in the shadow, the direction of the shadow will be known. Thus, in the last example, suppose the line *a o* obtained: since the point *o* is the beginning of the shadow of the line *b d*, produce *a c* and *b d*, to meet in V; join *o* V and draw the ray of the sun, *d p;* then *o p* is the shadow of *b d:* produce *d r* and *c s* to meet in L, and join *p l;* draw the ray *r q* from *r*, and *p q* will be the shadow of *d r*, not seen.

Proposition VII.—*To find the vanishing-line of a pole upon several planes.*

Plate II. *Figure* 1.—Let A B C D E F G H I K be the outline of a building, with a lean-to, or penthouse, D E N P O: V is the vanishing-point of all horizontal lines, in the gable, A B L I K, of the main house, and also of the gable, D M O C, of the penthouse; L^1 is the vanishing-point of all the horizontal lines in the parallel fronts, B F G L and D E N M; and as all vertical planes have vertical vanishing-lines, V R is the vanishing-line of the parallel gables, A B L I K and C D M O: L U the vanishing-line of the fronts, B F G L and D E N M; I L G H is the representation of the roof of the main building, and O M N P that of the penthouse.

Produce L I to meet V R, its vanishing-point, in S: draw S L^1, which will be the vanishing-line of the inclined plane L G H I, for S and L^1 are the vanishing-points of two lines in that plane: produce M O to meet V R in T, and draw T L^1; then T L^1 is the vanishing-line of the inclined plane M N P O of the roof of the penthouse, because T and L^1 are the vanishing-points of two lines in that plane.

Let W X be a pole resting upon the end of the house, in the same plane with the gable, A B L I K; and let Q be the vanishing-point of the sun's rays: produce the pole, X W, to meet V R in R; then R is the vanishing-point of the pole, or of the line that throws the shadow: therefore by drawing Q R, Q R will be the vanishing-line of the plane of shade, and let it cut V L^1, the vanishing-line of the horizon, in Y; and L^1 U, the vanishing-line of the vertical planes, B F G L and D E M N, of the walls, in U; V R, the vanishing-line of the gables, in R; S L^1, the vanishing-line of the main roof, in Z; and T L^1, the vanishing-line of the penthouse, in Z^1: all which does but prepare for drawing the shadow of the pole, W X, upon the horizontal plane and upon the building. Now produce A B to meet W X in X, then X will be the point where the pole rests upon the ground, or horizontal plane: draw X Y, cutting D E in *a;* draw U *a*, cutting D M in *b;* draw *b* R, cutting M O in *c;* draw *c* Z^1, cutting P O in *d;* draw U *d*, cutting G L at L; and draw L Z, cutting the ridge, I H, at *f;* then X *a b c d* L *f* will be the whole shadow of the pole.

For, since the shadow first begins at the foot of the pole, or line, in the plane of the horizon, and since the intersection of the vanishing-line of a plane on which the shadow is to be thrown, with the intersection of the vanishing-line of the plane of shade, gives the vanishing-line of the shadow

upon that plane; Y becomes the intersection of the vanishing-line of the plane of shade with the vanishing-line of the horizon; therefore Y is the vanishing-point of the shadow of the line W X upon the plane of the horizon. The next plane on which the shadow is thrown is D E N M; now L U is the vanishing-line of the plane D E N M, and U is the point where the vanishing-line of the plane of shade cuts L^1 U; therefore U is the vanishing point of the shadow upon the plane D E M N. The next plane on which the shadow is projected is the plane C D M O: now V R is the vanishing-line of the plane C D M O, and it intersects the vanishing-line of the plane of shade in R; therefore R is the vanishing-point of the shadow upon the plane C D M O. The next surface on which the shadow is projected is the plane, M N P O, of the roof of the penthouse: now z^1 is the intersection of the vanishing-line of the plane of shade with the vanishing-line T L^1 of the plane M N P O; therefore z^1 is the vanishing-point of the shadow on the plane M N P O. The next surface on which the shadow is projected is the plane, B F G L, of the wall; but U has already been shown to be the vanishing-point of the shadow. The plane of the roof is the last surface on which the shadow is projected: now S L^1 is its vanishing-line, and it meets the vanishing-line of the plane of shade in Z, therefore Z is the vanishing-point of the shadow upon the roof.

In carrying the shadow of a line across several planes, it will not be surprising if some little inaccuracy takes place from the obliquity of intersections; it might be a great chance, whether, when the part of the shadow, *d* L, which falls upon the plane B F G L, is drawn from the vanishing-point, U, through the point *d*, it will meet the pole at L, as it ought to do. To remedy this, begin with the shadow, L *d*, and proceed in the reverse order, until it meets the line W X at X, which it must in principle, and will not be liable to vary much in practice.

The points which direct the shadows upon the several planes, might also be found by the methods shown in the article PROJECTION.

The following observations will be useful in the practice of shadows.

When a straight line, that throws a shadow, is parallel to the picture, it is then represented parallel to the original. In this case it has no vanishing-point; or, in other words, the vanishing-point of the line may be said to be at an infinite distance: and, therefore, instead of the vanishing-point of the line being joined to the vanishing-point of the sun's rays, draw a straight line from the vanishing-point of those rays parallel to the projection of the line which throws the shadow, and it will be the vanishing-line of the plane of shade; therefore the intersection of the vanishing-line of the plane of shade with the vanishing-line of the plane on which the shadow is to be thrown, will give the vanishing-point of the shadow on that plane, after the same analogy as lines which are inclined to the picture. This case is similar to that of the sun's rays being parallel to the picture: for here, also, the vanishing-point of the rays is at an infinite distance; but as the plane of shade will still have a vanishing-line, this line will be found by drawing a straight line through the vanishing-point of the line that throws the shadow parallel to the sun's rays, as shown in a former example.

Of shadows projected from a given point; as by the light of a candle or lamp.

It is evident, if the representation of the luminous point be given, with its seat upon any plane, together with the representation of any point in space, and its representation upon that plane, the shadow of the point will be found by drawing a straight line from the luminous point through the point in space, and by drawing another straight line from the seat of the luminous point through the seat of the point in space; and the intersection of the two lines thus drawn will represent the shadow of the point upon the plane. But when the relation of several planes represented in a picture, the representation of the light with its seat, and the representation of a point in space with its seat, are given, to project the shadow of the point on the other planes, other considerations become necessary.

Figure 2.—For this purpose, let A B C D be the inside of a room, consisting internally of the vertical planes A H, E I, F K, G C, and of the horizontal planes A E F G B and D H I K C: also, let L be the luminous point, and M its seat in the plane A E F G B. In order to form an idea of the point L, in respect of the other planes, it is necessary to have the intersection of a line drawn through L, in a given position with one of the planes. Thus, if it is known that the straight line L *a*, parallel to the picture, cuts the plane of the wall, B K, in the point *a*; the position of the point L to any of the other planes may be easily determined, as follows:

Through *a* draw *a b* parallel to the vanishing-line, N O, of the plane B K, cutting B G, the intersection of the planes B K and A G, in *b*; through *b* draw *b* M parallel to P Q, the vanishing-line of the floor, cutting A E, the intersection of the planes A G and A H, in *c*; also F E, the intersection of the planes A G and E I, in *d*. Draw *c* Q parallel to N O, the vanishing-line of the plane A H; and *d f* parallel to R S, the vanishing-line of the plane E I. Then, because the intersecting and vanishing-lines of any plane are parallel to each other, and because a line drawn parallel to the intersecting line is parallel to the picture; therefore the representations of all the lines, *a b*, *b c*, or *b d*, *c* Q, and *d f*, are all parallel to the picture, and in a plane passing through the luminous point L.

Figure 3.—Given the vanishing-lines, A B, C D, E F, of three planes, G H I K, L M N O, and M N I Q R, the common intersection, N O, of the planes G H I K and L M N O; also the intersections, N I, and M N, of the planes G H I K and L M N O with the plane M N I Q R; the representation, *a b*, of a line in the plane L M N O; the point of light, *c*; *c d*, a line parallel to the picture; and *d*, the point where it intersects the plane M N I Q R: to find the shadow of the line on the plane G H I K.

First, find the representation of a ray of light parallel to the picture, thus: draw *d e* parallel to A B, cutting M N at *e*; draw *e f* parallel to E F: then if *a b* be not parallel to *e f*, produce *b a* to *f*, and join *f c*, which is the ray required. Secondly, find the vanishing-line of a plane of shade passing through the line *a b*, and the ray *f c*, thus: produce *a b* to meet C D in D, which is the vanishing-point of *a b*; through D draw D F parallel to *f c*; and D F will be the vanishing-line of the plane required. And, lastly, find the shadow of *a b* upon the plane G H I K, thus: produce O N and *a b* to meet in *g*; from F, through *g*, draw the line F *h i*; and from the point of light, *c*, draw *c b h* and *c a i*; then *h i* will be the shadow of the line, as required.

For *d e* being parallel to A B, the vanishing-line of the plane M N I Q R, *d e* will be parallel to the picture; and since *e f* is drawn parallel to E F, the vanishing-line of the plane L M N O, *e f* will be parallel to the picture; and because *b a* meets *e f* in *f*, *f c* is a ray of light parallel to the picture, meeting the line *a b*; and because C D is the vanishing-line of the plane L M N O, and *a b* is in the plane L M N O, therefore the vanishing-point of *a b* is in C D, and consequently at D, where *a b* produced meets C D: and because D is the vanishing-point of *a b*, the vanishing-line of the plane of shade will pass through D parallel to *f c*; but F is the intersection of the vanishing-line of the plane of shade, with the vanishing-line E F of the plane G H I K, on which the shadow is projected, therefore F is the vanishing-point of the shadow on the plane G H I K; and

because g is the intersection of $a\,b$ with the plane G H I K, the shadow will commence at g, and consequently drawing F $g\,h\,i$ gives the direction of the shadow; and, lastly, because c is the luminous point, the rays $c\,a\,i$ and $c\,b\,h$ will terminate the shadow.

As D would be the vanishing-point of all lines parallel to the original of $a\,b$ in the plane represented by L M N O; and as different representations could not meet the line $e\,f$ in the same point, the ray $c\,f$ will have different positions, as will consequently D F, which is drawn parallel thereto; and as the point D is stationary, the point F will be variable.

PROPOSITION VIII.—*Given the representation of three rectangular planes, forming a solid angle, the representation of a point of light, or candle, and the seat of the light on one of the planes; to find the seat of the light on the other two planes.*

Figure 4.—Let the three planes be A B C D, A B G F, A F E D. It is evident that every two adjoining planes have three edges parallel to each other, one common to both, which is their line of concourse; these edges will therefore vanish in a point, or be parallel to each other, according as the original planes are oblique or parallel to the picture; let the original planes be obliquely situated; therefore produce the sides C D, B A, G F, of the two adjoining planes A B C D, A B G F, and they will all meet in V, their vanishing-point; also produce the sides D E, A F, B G, of the two adjoining planes D A F E, F A B G, and they will meet in W, their vanishing-point; likewise produce the sides C B, D A, E F, and they will meet in X, their vanishing-point.

Let I be a luminous point, and S its seat in the plane A B C D: draw S X, cutting A B in a; draw a W, and draw I X, cutting a W, in s^1, then s^1 is the seat of the luminous point in the plane A B G F; draw S V, cutting A D in b; draw b W and I V, cutting each other in s^2, then s^2 is the seat of the luminous point in the plane A D E F.

Because the plane A B C D represents a rectangle, and V is the vanishing-point of the one side, and X that of the other; all the lines drawn to X will represent right angles with the lines which vanish in V; therefore S a and A B represent a right angle in the plane A B C D. For the same reason, $a\,s^1$ represents a right angle in the plane A B G F; and since the planes A B G F and A B C D are at right angles, the angle S a s^1 will represent a right angle; and because a S represents a perpendicular to A B, $a\,s^1$ and S I will represent parallel lines; and since I s^1 and S a have the same vanishing-point, X, the original of I s^1 is parallel to the original of S a; but S a represents a perpendicular to the plane A B G F, therefore I s^1 also represents a perpendicular to the plane A B G F; and because the point s^1 is in the plane A B G F, s^1 is the seat of the luminous point L, in the plane A B G F. In the same manner it may be shown that s^2 is the seat of the luminous point in the plane A D E F.

PROPOSITION IX.—*Given the representation, c d, of a line perpendicular to the original of the plane* A B C D, *and the vanishing-point,* W, *of the line, and the point, d, where the line meets the plane* A B C D, *a luminous point* I, *with its seat* S, *also upon the plane* A B C D; *to find the shadow of the line* C D *upon the said plane.*

Draw S d and I c to meet each other in e, then $d\,e$ will be the shadow of the line $c\,d$, as required. In the same manner, if $f\,g$ represent a line perpendicular to the plane A B G F, and g the point where it meets the plane A B G F, $g\,h$ will be the shadow of the line, by drawing I f and s^1 g to meet in h.

This method is general for any position of the original planes with respect to the picture; and this position of the planes in respect of each other, is that which most frequently occurs in practice.

Figure 5—Let A B C D be the inside of a room, showing five sides, one, E F G H, being parallel to the picture, and the other four perpendicular to it; c^1 being the centre of the picture.

Let L be the light of a candle, S its seat upon the floor; then to find the seat of the light on all the other four sides: through S draw $a\,b$ parallel to V L^1, the vanishing line of the horizon, cutting B F at a, and C G at b; draw $a\,s^1$ and $b\,s^2$ parallel to Y Z, the vanishing line of the two vertical planes; through L, the point of light, draw $s^1\,s^2$, then s^1 is the seat of the light in the plane A B F E, and s^2 the seat of the light in the plane C D H G. Produce C S to meet B C in c; draw $c\,d$ parallel to Z Y, and join $d\,c^1$; draw S s^3 parallel to Y Z; then s^3 is the seat of the light in the plane A E H D; let C S cut the line F G in e; draw $e\,s^4$ parallel to Z Y, cutting L c^1 in s^4, then s^4 will be the seat of the light on the plane E F G H. Then, to project a prism standing perpendicular to any of these planes, suppose that which stands on the floor: from the seat, S, draw S i, meeting C G in o; draw $o\,r$ parallel to Z Y, and draw the ray L $m\,r$; then r will be the shadow of the point m; draw S h, cutting C G in p; draw $p\,s$ parallel to Y Z, and draw L n, cutting $p\,s$ at s; then s is the shadow of the point n; also draw S g, meeting C G in q; draw $q\,t$ parallel to Z Y, and L k, meeting $q\,t$ at t; then t is the shadow of the point k; join $r\,s$ and $s\,t$, which will complete the whole shadow of the prism upon the floor, and on the wall.

The principle of finding the shadows of the prisms on the other sides, is the same, and will be obvious to inspection. The truth of the method has already been shown.

SHAFT, (from the Saxon *sceaft,*) that part of a column which, in the classic examples, may be denominated *the frustrum of a conoid*, situate between the base and capital; it is also called *the fust, trunk,* or *body of the column.*

By some architects, columns are diminished from one-third upwards; this occasions a very gouty appearance. Some architects and builders, however, have fallen into the contrary error, by making the sides of columns in a straight line from the base to the capital. Mr. Revely, in his Preface to the third volume of Stewart's *Athens*, expressly says, that all the columns he had seen in Greece were diminished with a gentle curve. The curve is so gentle, that the straight line, which is a tangent at the bottom of the shaft, is not parallel to the axis, but falls nearer to it at the top of the column than at the bottom. For the method of diminishing the shaft of a column, *see* COLUMN.

The method of drawing the shafts of columns upon paper in the most expeditious manner, will be a very useful addition to this article.

Figure 1.—*To represent a fluted column, the height of the column, its diameter at the bottom, and the ratio of the two diameters, being given.*

Let A B represent the height and axis of the column, produce A B to C, make A B + B C to B C in the ratio of the diameter at the base, to its diameter at the capital; draw a line through A, and another through B, at right angles to A B; set half the diameter of the column from A on each side of it, and divide the whole length of this line into parts representing the ratio of the flutes orthographically projected; from the points of division draw lines to C, to meet the line passing through B, and the lines thus drawn will represent the shaft of a column as fluted.

In this example A B + B C is to B C as 4 to 3, therefore the point C will be found by repeating A B four times from A to C.

Figures 1, 2, 3, 4, represent a range of columns, three of which are here supposed to be drawn by this or the fol-

lowing means, which will be made sufficiently plain by reference to the plate:—

Suppose a compass joint-rule, as in *Figure* 4, bevelled on the upper sides of the inner edges; from R, the centre of the joint, set on the inner edge R P as many times the height of the shaft, P Q, as the diameter at the bottom contains the difference of the two diameters; lay the edge of the rule upon the axis, with the point P on the middle of the bottom diameter, S U; draw the other leg of the rule out to any convenient distance, while the marked leg is kept fast upon the axis; then pressing down the leg which is not over the work, move the marked leg to any point in S U, and draw a line by it, which will represent a flute; and all the other flutes may be drawn by repeating the operation. If the two lines which terminate the breadth of the column be continued downwards to D and G (*Figure* 1) at the waste edge of the paper, and also the axal line A B, the fluting may be projected by means of the semicircle D H I G; the line D G being supposed at right angles to A B. On D G describe a semicircle, and draw the tangent line E F parallel to D G, cutting C D and C G at E and F; then from E and F draw lines to the centre, cutting the circumference at H and I; divide the arc H I into five equal parts, set two on the arc H D, and two on the arc I G, which will be the points for the angles on the semi-circumference; and from these points draw lines to C between the diameters at A and B.

Figures 1, 2, 3, 4, are four equal shafts of columns, placed at equal distances, and supposed to constitute a part of the drawing of a Doric portico. The method of drawing the flutes to a point is most expeditiously performed by means of a joint-rule in the following manner:—Whatever be the intended height of the drawing of the shafts, set as many times that height from the centre of the joint on the inner edge of the rule, as the diameter of the column at the bottom contains the excess of that diameter above the upper diameters. Let us suppose that the upper diameter is to the lower as 3 to 4, as in the plate, then P Q being the representation of the height of the shaft, make R P on the edge of the rule equal to four times P Q; and lay the edge R P on the line representing the axis of the column; while R P is in this position, move the other leg out to any distance, and press upon it so as to make it stationary; then revolve the leg that was first stationary, and the point R will still keep its situation in the axis of the column, so that the moveable leg of the rule, moving round the centre of the joint, will answer the same purpose as a straight-edge moving round a pin; but it is much handier, for if the point falls on the paper, we shall have no occasion to prick it; and if the point extends beyond the surface of the board, we can still use the joint-rule with as much correctness as if the point were in the drawing board. *Figures* 5 and 6 exhibit a very correct modification of the principle just explained. Find the point V as above, extend the axal line V W to the bottom of the board at *h*, where the paper is intended to be cut off when the drawing is finished; then if the upper diameter is to be one-sixth less than the lower diameter, divide *a b*, *Figure* 6, of the same length into six equal parts, and if the column be eight diameters in height, divide the lower sixth part into eight equal parts; then on the point *h* describe the semicircle *c, i, k, d;* with a radius equal to one of these parts, circumscribe the rectangle *c, f, e, d*, and divide the flutes as before.

Figure 7 is the method of drawing the flutes by dividing both diameters in the same ratio as shown by the plan at the bottom.

SHAFT OF A CHIMNEY, the stone or brick turret above the roof. *See* CHIMNEY.

SHAFT OF A KING-POST, the prismatic part between the joggles.

SHAFTED IMPOST, an impost which has horizontal mouldings separating the archivolt from the pier, and where the section of the archivolt is different from that of the pier. Imposts are termed *shafted*, to distinguish them from *banded* imposts, in which the sections above and below the impost-moulding are alike, the shaft or pier seeming to pass through its capital.

SHAKE, or SHAKEN, a term applied to timber that is rent by drying too suddenly; in which the fissure, occasioned by too great a heat, is called *a shake*.

SHAKY, or SHAKEN, a natural defect in timber when full of splits, or clefts.

SHAM DOOR, in joinery, a panel of frame-work, that appears like a door, but does not open. Sham doors are necessary where corresponding symmetry is wanted; they are only wrought and moulded on the side next to the room. *See* DOOR.

SHANK, (from the Saxon *sceanca*,) a name given to the intersticial spaces between the channels of the triglyph, in the Doric frieze; they are sometimes called *the legs of the triglyph*, and by Vitruvius, *femur*.

SHEERS, a machine employed for lifting heavy and cumbrous materials, consisting of two lofty beams or legs of wood, placed vertically, united at the top, and set apart at the feet; a capstan rope passes over a pulley at the top, by means of which the weight is raised.

SHEET LEAD. *See* PLUMBERY.

SHELVES, (from the Saxon *cylf*,) boards fixed against a wall by their edges, and with their sides horizontally disposed, for the purpose of setting articles upon them. Shelves are supported below by brackets, which are either solid pieces, or small trusses; they are also supported at the ends with vertical pieces, called *standards*, or *cut standards*, where they are let in, and moulded on the edge.

SHIDES, or SHINGLES. *See* SHINGLES.

SHINGLES, (from the German *schindel*,) small boards, similar to slates, prepared for covering a building. They are of oak, either sawn or cleft, about an inch thick at one end, thinned off towards the nail or pin; about 4 inches broad, and from 8 to 12 inches in length. This kind of covering is very dear, and seldom used but for the roofs of churches and pyramidal steeples. Nevertheless, when a light covering is required, shingles may be employed with propriety. Before they are used, they should be well seasoned, by steeping them in water, and drying them in the sun. When made of good cleft oak, this covering is preferable to thatch.

SHINGLING, the act of covering a roof with shingles. In this operation, the building must be first covered all over with boards, after which the rest of the process is similar to that of slating. *See* SLATING.

SHOAR, or SHORE (from the Saxon *score*,) among builders, a prop, or oblique timber, acting as a brace upon the sides of a building, the wall itself performing the office of a post, and the ground that of a beam; so that the wall and ground are ties, while the post is a straining-piece. The upper ends of shores should always rest against that part of the wall into which a floor is inserted, in order to make a counter-resistance to its action. Both ends of shoars should rest upon plates, or beams, which, if firmly fixed, will form a much stronger resistance than could be obtained without them. They should be tightly trimmed between the plates, by driving wedges under their lower ends.

SHOAR, *Dead*, an upright piece of wood, built up in a wall, which has been cut or broken through in order to make some alteration in the building. The piece of wood thus enclosed, being necessary for the support of the superincumbent part

during the making good of the wall, and left for the security of the work, which would otherwise be in danger of shrinking, and thereby occasion a fracture in the building.

SHOARING, *See* SHOAR.

SHOE (from the Saxon *sceo* or *scoe*,) the part at the bottom of a water-trunk, or leaden pipe, for turning the course of the water.

SHOOT, a term expressive of the act of planing the edge of a board straight, and out of winding.

SHOOTING-BOARD, two boards fixed together, with their sides lapped upon each other, so as to form a rebate, for the purpose of making short joints, either oblique to the fibres, or in their direction. By this instrument, the joints of the panels of framing are made, as also those of the mitres of architraves, or the like.

SHOULDER OF A TENON, the transverse plane to the length of a piece of timber, from which the tenon projects. The shoulder should always be at right angles to the length; though it does not always lie in the same plane as here defined, but sometimes in different planes; as, in the binding-joists of a floor, the shoulder consists of two parallel planes, and one oblique plane. As this compound shoulder seldom or never takes place in anything else, it is simply defined, as above, by its form, in order that the meaning may be more easily comprehended; however, it may be generally defined thus: a shoulder is that which can only be resisted when the piece is pushed forwards in the same direction, supposing the piece, and that which resists it, to be polished.

SHOULDERING PIECES, *See* BRACKETS.

SHREAD HEAD, or JERKIN HEAD, *See* JERKIN HEAD.

SHREDINGS, (from the Saxon *screadan.*) In the roofs of many old buildings, the rafters were formed with a knee, or an obtuse exterior angle from the outside, at the bottom, the upper part, above the knee, being straight to the ridge; and the lower part, which rested upon the wall, either plumb, or nearly so: in order to support the slating between the knee and the face of the building, short slight pieces, as bearers, were fixed below, forming a straight line with the upper part of the rafters; these were called *shredings*, or *furring*, of which, the latter term is most commonly used. *See* FURRINGS.

SHRINE, a tomb in which the remains or relics of some saintly or noble persons were deposited. They are usually of a highly decorative character; fine examples exist in many of our cathedrals; there is one of Edward the Confessor in Westminster Abbey; it is of stone, and measures 15 feet in height; there is another of St. Frideswide at Oxford, but this is of wood, date about 1480.

The term is also applied to small caskets to contain relics, usually in the shape of rectangular boxes with coped coverings; they are mostly of metal, or overlaid with metal, and enriched with precious stones and other valuables.

SHRINKING, the contracting of a piece of timber in its breadth, by seasoning, hot weather, &c. The shrinking of a piece of timber is proportioned to its breadth. The length of timber is unalterable by seasoning, or any kind of weather; and hence it is, that, in unseasoned timber, mitred together, such as the architraves of doors and windows, the mitres are always close on the outside, and open towards the door, forming a wedge-like hollow on each side of the frame. It is to avoid the shrinking of timber, that narrow boards, called *battens*, are used in floors; and when the panels of a piece of framing are very broad, they will shrink so much as to fall out of the grooves.

SHUTTERS, the boards, or framed joinery, by which the aperture of a window is closed. *See* JOINERY.

When shutters are made like boards, they are generally clamped, to keep them from warping; in this case they are seldom less than three-fourths of an inch thick. Framed shutters are either square, or moulded on one or both sides: in the latter case, the mouldings on the outside are made to correspond with the doors in the same room. Framed shutters are seldom less than $1\frac{1}{4}$ inch thick. The thickness of shutters generally depends upon the mouldings, which will occasion the panels to be more or less sunk, according as they are placed on one or both sides. Shutters are sometimes cut, that they may fold more readily together; in this case, they have usually a bead attached to one of them, most commonly to the upper one, by which means the ends of the styles are completely covered. Shutters should not be cut for wide windows, such as those of the Venetian kind; for, in consequence of the cutting, the hinges have less power to support them, and they become liable to go wrong. In shutters, the parts that are hinged together are called *folds;* and those folds that appear when the others are depressed within the boxings, are called *front shutters;* while those that are only seen when the aperture is shut, are called *back flaps*, or simply *flaps:* these, in ordinary works, are generally made thinner than the front shutters, and are mostly clamped, or square-framed. *See* BOXINGS OF A WINDOW, and SASH-FRAME.

SIDE POSTS, a kind of truss-posts, placed in pairs, each particular post being disposed at the same distance as the rest from the middle of the truss. Their use is not only for the support of the principal-rafters, braces, crown or camber-beams, but also to hang the tie beam below. In extended roofs, two or three pairs of side-posts are employed, with frequently a middle-post, king-post, or crown-post besides, as the whole stress of the roof must be thrown either to the middle-post, or, in case there is no middle-post, to the two side-posts next the centre; these posts must then act upon each other by the intervention of struts. Posts of a roof are most commonly cut into joggles, which are butments, against which the shoulders of the tenons of the struts rest, and then the butments are at right-angles to the length of the struts. The side-posts of a truss, where the principal-rafters meet, sustain as many points, both in the principal-rafter and in the tie-beam, as they are themselves in number.

SIDE TIMBERS, a term used in Somersetshire for purlins. *See* PURLINS.

SIDE WAVERS, a term used in Lincolnshire for purlins. *See* PURLINS.

SILL, or CILL, (from the Saxon *syl*,) in carpentry, a beam disposed in the lower part of walls, or upon the tops of joists, or under apertures. *Ground-sills* are those upon which the posts and superstructure of a timber building are raised. *Door* and *window sills*, sufficiently indicate their place by their names. The bottom pieces, on which quarter and truss partitions are raised, are called *sills.* Sills are either supported throughout their whole length, as in ground and window sills; or in many points, as those of partitions by joists.

SIMA. *See* MOULDINGS.

SIMA-INVERSA, *See* MOULDINGS.

SIMA-RECTA, *See* MOULDINGS.

SIMA-REVERSA, *See* MOULDINGS.

SIMILAR FIGURES, those of which the several angles are respectively equal, with the sides about the equal angles proportionate.

SINGLE FLOOR, *See* NAKED FLOORING.

SINGLE FRAME AND NAKED FLOOR, a floor with only one tier of joists.

SINGLE-HUNG, an expression applied to window-sashes, when only one of them is moveable in the same vertical plane.

Single-joist Floor, a floor without binding-joists.

Single Joists, those which are employed singly in a floor.

Single Measure, a term applied to a door that is square on both sides. It stands opposed to *double measure*, or moulded on both sides. When doors are moulded on one side, and square on the other, they are accounted measure and half.

SITE, the situation or locality of a building, &c.; the plot of ground on which it stands.

SKEW ARCH, an arch, the face of which stands obliquely with reference to the inner faces of the piers. *See* a description of a Skew Bridge in the article Stone Bridge.

SKEW-TABLE, a stone built at the bottom of a gable, to carry the raking coping above. The term is of rather doubtful application; and is employed also to signify the coping itself, consisting of either slabs or solid blocks, toothed into the masonry of the walls. It may be, perhaps, further applied to the sloping projecting rib of masonry frequently seen over gable-ends of roofs, where they abut against vertical walls of greater height than the apex of the roof; as when the roof of the nave of a church abuts against the side of a tower.

SKIRTINGS, or Skirting Boards, the narrow boards round the margin of a floor, forming a plinth for the base of the dado, or simply a plinth for the room itself, should there be no dado. The skirting is either scribed close to the floor, or let into it by a groove; in the former case, a fillet is put at the back of the skirting, to keep it firm.

SKIRTS, (from the Swedish *skiorte*,) one or more superficies, laid in plano, but which would cover a body without leaving any interstice, or without any one part lapping upon another. The four sides of a room, when laid out in this manner, are called *skirts;* as are also the sides of a roof laid out upon a plane.

SKREEN, (from the French *escran*) the instrument used by labourers in sifting earth, lime, &c., for making mortar.

SKYLIGHTS, glass frames placed in a roof with one or more inclined planes of glass. Skylights are either in one plane, as when placed in the inclined side of a roof, or pyramidal, conical, conoidal, spherical, or ellipsoidal, when they are placed above the roof; in which last cases the axis is perpendicular, with the vertex, of course, above. Plane skylights, the most common of all, are sometimes made to slide: the pyramidal have a more grand appearance; but the most dignified is the conical and conoidal, particularly when the ceiling below forms a dome. The spherical and ellipsoidal are less graceful than the conical or conoidal, and much more troublesome to execute. In all skylights, it is necessary that the joint between the bottom and the curb on which they rest, should be so secured as to prevent water running through. Plane skylights, not intended to open, are fixed in the following manner: the upper side of the skylight is bevelled all round the edge of the frame; a row of slates is fixed at the bottom of the aperture; the skylight is then fixed, and the other three sides covered in the process of slating.

SLAB, an outside plank, or board, sawn from the sides of a timber tree, and frequently of very unequal thickness.

The word is also employed to express a thin piece of marble, consisting of right angles and plane surfaces.

SLATE, a bluish fossil stone, very soft when dug out of the quarry, and thereby easily cut or sawed into long thin squares, to serve instead of tiles for the covering of houses, making tables, &c.

SLATING, is employed, in architecture, in sundry ways, the principal of which refers to the covering of the roofs of buildings, but such has been lately the perfection of working in slate, that it is now wrought and fitted into many useful utensils, as well as made up into balconies, chimney-pieces, casings to walls, skirtings, staircases, &c.

The slate principally used in London is brought from Wales, taken from quarries on Lord Penrhyn's estate at Bangor, Caernarvonshire, whence it is forwarded to all parts of the United Kingdom. There are also some other kinds of slate in use, the best sort of which is brought from Kendal, in Westmoreland, and is called *Westmoreland slate.* These are of a fine pale bluish-green colour, and are most esteemed by architects. They are not of a large size, but of good substance, and well calculated to give a neat appearance to a roof. The Scottish slate is nearly similar in size and quality to a slate from Wales called *ladies*, but they are very little sought after.

French slates, which were very much in use many years since, are small in size, most commonly not larger than the Welsh doubles, extremely thin, and, consequently, light; but their composition has been found to be not well adapted to this climate, where the atmosphere contains an excess of moisture. By analysis, this slate is ascertained to contain $\frac{1}{30}$ of manganese, besides other matters, such as iron, &c., the excessive affinity of which for oxygen soon shivers the stony portion of the slate, when employed as a covering, in this country.

Slaters class the Welsh slates after the following order and designations, *viz.*

	Ft.	Inch.		Ft.	Inch.
Doubles, average size,	1	1	by	0	6
Ladies,	1	3	by	0	8
Countesses,	1	8	by	0	10
Duchesses,	2	0	by	0	12
Welsh rags,	3	0	by	2	0
Queens,	3	0	by	2	0
Imperials,	2	6	by	2	0
Patent slate,	2	6	by	2	0

The *doubles*, so called from the smallness of their size, are made from fragments of the larger qualities as they are sorted.

The *ladies* are similarly obtained, but in pieces that will square up to the size of such description of slate.

Countesses are a gradation above *ladies;* and *duchesses* still larger.

The slate is extracted from the quarries, as other stony substances usually are, that is, by making perforations between its beds, into which gunpowder is placed and fused. This opens and divides the beds of the slate, which the quarrymen remove in blocks of very considerable size. These blocks are aftewards split by driving iron wedges between their layers, which separates them into scantlings of from four to nine inches in thickness, and as long and wide as may be required. Such of the scantling as is intended for exportation is sawn to the sizes ordered.

For the purpose of sawing the slate, the works in Wales are provided with abundance of ingenious machinery, some of which are put in motion by steam, and others by water, which keep in action a vast number of saws, all cutting the scantlings into pieces adapted to their several purposes.

The *imperial slating* for roofs is uncommonly neat; and is known by having its lower edge sawn, whereas all the other slates, used for covering, are chipped square on their edges only.

The *patent slate* is so called, among the slaters, from the

mode adopted to lay it on roofs, as no patent was ever obtained for such a mode of slating. It was first brought into use by Mr. Wyatt, the architect. It allows of being laid on a rafter of much less elevation than any other kind of slate, and is considerably lighter by reason of the laps being less than is necessary for the common sort of slating. This slating was originally made from that description of slates known as *Welsh rags*. The slaters now frequently make it of imperials, which renders it still lighter, and somewhat neater in its appearance. Experiments have been instituted on the Westmoreland slate by the Bishop of Llandaff, from which there appears very little difference in its natural composition from that obtained from Wales.

Thirteen loads of the finest sort of Westmoreland slate will cover 42 square yards of roofing, and 18 loads of the coarsest will cover the same quantity; so that there is half a ton less weight put upon 42 square yards of roof when the finest sort of slate is used, than if it were covered with the coarsest kind, and the difference of expense is very trifling. It must be remarked, that it owes its lightness, not so much to any diversity in the component parts of the stone from which it is split, as to the thinness to which the workmen reduce it; it is therefore not so well calculated to resist violent winds as that which is heavier.

All the kinds before named partake of a similar mode of laying, in as far as refers to the *bonding* or *lap* of one portion of the slate over another. The lap of each joint is generally equal to *one-third* of the length of the slate, and the slater selects all the largest of the description about to be used, to be put on nearest the eaves. When the slates are brought from the quarry, they are not so square as to be immediately fit for use, but are prepared by cutting and sorting. The slater, to effect this, picks and examines the slate, observing which is its strongest and squarest end. He then, by holding the slate a little slanting upon, and projecting about an inch over the edge of a small block of wood, seating himself at the same time on something which is equal to it in height, cuts away straight one of its edges: next, with a slip of wood, he gauges the other edge parallel to the same, and cuts off that also; after which he turns it round and squares the end. The slate is so far prepared, excepting it be the turning of his tool round and pecking through it, on its opposite end, two small holes, which are made for the nails to enter when he lays it on the roof. All the quarry slates require this preparation from the slater. All slates are put on with nails or screws, and two, at least, are assigned to each slate. The copper and zinc nails, or iron nails tinned, are esteemed the best, as being less susceptible of oxidation than those of bare iron.

The preparation necessary for laying slates on roofs, consists in forming a base or floor for the slates to lie compactly and safely upon. For the *doubles* and *ladies*, boarding is essential, if it be expected to have a good water-proof covering. All that is required in the boarding for such slates is, that it be laid very even, with the joints close, the boards being properly secured by nailing them on the rafters.

When the boarding is ready, the slater examines it, and provides himself with several slips of wood, called *tilting fillets*. A tilting fillet is made about two inches and a half wide, three-quarters of an inch thick on one edge, and chamfered away to an arris on the other. These fillets he carefully lays and nails down all round the extreme edges of the roof, beginning with the hips, if any, and, if not, with the sides, eaves, and ridge. When these are all done, he prepares for laying the slates, and begins at the eaves first. For these he picks out all the largest slates, and places them regularly throughout, setting their lower edges to a line; after which, he secures them by nailing them down to the boarding. He then selects such slates as will form the bond to the under sides of the eaves. This part of the work consists in placing another row of slates under those which he has previously laid, so as to cross and cover all their joints; such slates are pushed up lightly under those which are above them, and are seldom nailed, but left dependent for their support on the weight of those above them, and their own weight on the boarding. The *countesses*, and all other descriptions of slates, when intended to be laid in the best manner, are also laid on boards. When the slater has finished the eaves, he strains a line on the face of its upper slates parallel to its outer edge, and as far from it as he deems sufficient for the lap of those slates which he intends shall form the next course, which is laid and nailed even with the line, and crossing the joints of the upper slates of the eaves. This lining and laying of the slates is continued till the slater gets up close to the ridge of the roof, observing throughout to cross the different joints by the slates he lays on, one above another. This method is uniformly followed in laying all the different kinds of slates, excepting what are called *the patent* slates, as will be hereafter explained. All the larger kinds of slate are found to lie firmly on what are called *battens*, in consequence of which they are frequently made use of for the sake of economy, being cheaper than the smaller slates laid on boarding. A batten consists of a narrow portion of deal wood, about two inches and a half, or three inches wide; three of which are commonly taken out of a deal. When *countesses* are to be laid on, battens of three-quarters of an inch in thickness will be an adequate substance for them; but for the larger and heavier kind of slates, inch battens will be necessary. When a roof is to be battened for slates, the slater himself is the best person to fix them, as they are not placed at a uniform distance from each other, but so as to suit the lengths of the slates; and as these vary as they approach the apex or ridge of the roof, it follows that the slater himself becomes the best judge where to fix the batten so as best to support the slates.

The patent slating, as it is called, consists in selecting the largest slates, and those also of uniform thickness. A roof to be covered with this kind of slate, requires that its *common* rafters be left loose upon their purlins, as they must be placed so as to suit the widths of the slates, it being necessary to have a rafter under every one of their meeting joints. Neither battening nor boarding is required for these slates, and the number of rafters will depend on the width of the slates; hence if they are of a large size, very few will be required, and of course a great saving in the timber takes place, besides giving much less weight upon the roof. The work of covering by this kind of slating is commenced, as before, at the eaves, but no crossing or bonding is wanted, the slates being uniformly laid, with each end reaching to the centre of a rafter, and they are all butted up to each other throughout the length of the roof; the rafters being so placed as to come regularly under the ends of two of the slates. When the eaves course is laid, the slates composing it are all screwed down by two or three strong inch-and-a-half screws at each of their ends into the rafters. A line is then strained about two inches below their upper edge, this being allowed as a lap for the next course of slates, which is laid on above, with its edges straight with the line; and this lining, laying with a lap, and screwing down, is continued till the roof is finally covered. The joints are then to be secured by filleting, which consists in covering all the meeting joints with fillets of slate, bedded in glazier's putty, and screwed down through the whole into the rafters. The fillets are usually about three inches wide, and as long as the slate they are

intended to cover. They are solidly bedded in the putty and their intersecting joints are lapped as those of the slates; one screw is put in each lap, and one in the middle of the fillet. The fillets, being so laid, are neatly pointed up all round their edges with more putty; and are lastly painted over the colour of the slate. The hips and ridges of such slating are frequently covered by fillets in a similar way, and have a very neat effect. But lead is the best covering for *all* hips and ridges of roofs, and it is not much dearer than covering them by this mode.

The patent slating may be laid so as to be perfectly watertight, with an elevation of the rafters considerably less than for any other slate or tile covering; a rise of two inches in each foot of the length of the rafter being deemed sufficient; and this, for a rafter of fifteen feet, would be only two feet six inches, a rise in the pitch of a roof, which, on any height from the ground, would be hardly perceived.

Slating is done also in several other ways, but the principles before explained embrace the most of them. Some workmen shape and lay their slates in a lozenge-form. This kind of work consists in getting all the slates to a uniform size, and the shape of a geometrical square; when laid on the roof, (which is always boarded for this work,) they are bonded and lapped as in common slating; observing only to let the elbow, or half of the square, appear above each slate that is under it, and to be regular in the courses all over the roof. One nail or screw only can be used for such slating, hence it soon becomes dilapidated. It is commonly employed in places near to the eye, or where particular neatness is required.

Slaters' tools consist of a few only, which are sometimes found by the master, and sometimes by the men. The tool, called the *saixe*, is composed of tempered iron, about sixteen inches in length, and two inches in width, somewhat bent at one end, with a beech handle at the other.—This instrument is not unlike a large knife, except that it has on its back a projecting piece of iron, about three inches in length, and drawn to a sharp point. With this tool, ground sharp, the slater chips or cuts all his slates to the required sizes.

The *ripper* is of iron, about the same length as the saixe, and very thin in its blade, which is one inch and three-quarters wide, tapered somewhat towards its top, where it has a round head projecting over the blade about half an inch on each side, and having also two little round notches in the two internal angles, at their intersection. At the handle-end of this tool there is a shoulder, which raises it up above the blade, and enables the workman to hold it firmly in his hand. The use of this tool is in repairs of old slating, as by forcing up its blade under the slates, the projecting head catches the nail in the little notch at its intersection, and enables the workman to pull it out, at the same time that it loosens the slate, and allows him to remove it, and insert another in its place.

The *slater's hammer* is somewhat different in shape from the common tool of that description; it is on the hammer, or driving part, about five inches in height, bent on the top a little back, and ground to a tolerably sharp point; its lower or flat end being about three-quarters of an inch in diameter, and quite round. On the side of the driving part is a small projection, with a notch in its centre, which is used as a claw to extract such nails as do not drive satisfactorily.

The *shaving-tool* is used for getting the slates to a smooth face for skirtings, floors of balconies, &c. It consists of an iron blade, sharpened at one of its ends like a chisel, and mortised through the centre of two round wooden handles, one of which is fixed at one end, and the other about the middle of the blade. The blade is about eleven inches long, and two inches wide; the handles are about ten inches long, so that they project four inches on each side of the blade. In using this tool the workman takes it in both his hands, placing one hand to each side of the handle in the middle of the blade, and allowing the other to press against both his wrists; in this manner he works away all the uneven parts from off the surface of the slate, and gets it to a smooth face.

The slater's other working tools consist of numerous *chisels* and *gouges*, together with *files* of all sizes, with which he finishes his slates for the better parts of his work into mouldings, and other forms.

The strength of slate is very great in comparison of any kind of freestone, as it is ascertained that a slate of one inch in thickness will support, in an horizontal position, as much in weight as five inches of Portland stone, similarly suspended. Hence, slates are now wrought and used for galleries and other purposes, where strength and lightness combined are essential.

Slates are also fashioned into chimney-pieces, partaking of the different varieties of labour applied to marble; but it is incapable of receiving a polish like it, except by japanning. It makes excellent skirtings of all descriptions, as well as casings to walls where dilapidations, or great wear and tear, are to be anticipated. It is capable of being fixed, for these purposes, with joints equally neat with wood, and may be painted over if required, to appear like it. Staircases may be executed in slate, and will have an effect not unlike to black marble.

Slaters' work is measured by the surveyors, as most artificers' work now usually is, and is afterwards reduced into squares, each square containing 100 feet superficial.

Slaters are allowed, in addition to the nett dimensions of their work, (when taking the measure of roofs,) six inches for all the eaves, and four inches for the hips; this allowance is made in consequence of the slates being used double in the former case, and for the waste in cutting away the sides of the slates to fit into the latter. Some of these eaves, for instance, when *rags* or *imperial slates* are used, require an additional allowance of nine inches for the eaves, such kind of slates being so much larger than the size of most of the other kinds now in use. All faced work in slate skirtings, staircases, galleries, &c. is charged by the foot superficial, without any addition. Chimney-pieces are made up and sold at per piece, by the masons.

The following Table of Comparisons will be found useful:

	Average gauge when laid	1200 will cover squares.	Weight per thousand of 1200 in tons.	Nails required to a square.	
				Iron, cast or wrought at per hundred.	Copper at per lb.
	Inches.				
Doubles	5½	2¼	¾	480	5
Ladies	7	4½	1¼	280	3
Countesses	10	7½	2	320	3¾
Duchesses	11	10	3	254	2¾

SLEEPERS, a row of horizontal timbers, disposed in a building, next to the ground, transversely, under walls, ground joists, or the boarding of a floor.

In bad foundations, sleepers are laid upon piles, and planked over, in order to support the incumbent walls. Sleepers under ground-joists, either lie upon the solid earth, or are supported in several places of their length by prop-stones: when in the former position, having no rows of timbers below,

these ground-joists are themselves called *sleepers*. Old writers of practical architecture call those rafters which lie in the valley of a roof by the name of *sleepers;* but the word, applied in this sense, is quite antiquated: such rafters take the name of the place under which they are disposed, that is, they are called *valley rafters*, or, more simply, *valleys*.

SLIDING-RULE, a rule constructed with logarithmic lines, formed upon a slip of wood, brass, or ivory, inserted in a groove, in a rule, made to slide longitudinally therein, so that by means of another scale upon the rule itself, the contents of a surface, or solid, may be known. This rule has already been described under the article CARPENTER'S RULE: but as no examples of its use are given under that head, we shall here supply them. To make the matter more intelligible, we shall here state that all squares are to be found upon C, the side, and all roots upon D, the scale adjoining the slide next to the folding-joint; then, whatever value is put on the 10 on D, the value on C will be the square of that on D. A mean proportional, or root, or given side, is to be found on D. The line C contains squares, lengths, and contents of solids. In finding a mean proportional, set the least number on C to the same on D, then against the greater, on the side, stands the mean on D.

EXAMPLE 1. *To multiply numbers together, as* 12 *and* 16.—Set 1 on B, to the Multiplier (12) on A; then against the multiplicand (16) on B, stands the product (192) on A.

EXAMPLE 2. *To find the product of* 35 *and* 19.—Set 1 on B, to the multiplicand (35) on A; then, because 19 on B runs beyond the rule, I look for 1.9 on B, and against it, on A, I find 66.5; but the real multiplier was divided by 10, therefore the product 66.5 must be multiplied by 10, which is done by taking away the decimal point, so the product is 665.

EXAMPLE 3. *To divide one number by another, as* 360 *by* 12.—Set the divisor (12) on A, to 1 on B; then against the dividend (360) on A, stands the quotient (30) on B.

EXAMPLE 4. *To divide* 7680 *by* 24.—Set the divisor (24) on A, to 1 on B; then because 7680 is not contained on A I look for 768 on A, and against it I find 32 on B, the quotient; but because one-tenth of the dividend was taken to make it fall within the compass of the scale A, the quotient must be multiplied by 10, which gives 320.

EXAMPLE 5. *To square any number, as* 25.—Set 1 upon C to 10 upon D. Then observe, that if you call the 10 upon D 1, the 1 on C will be 1; if the 10 on D be called 10, then the 1 on C will be 100; if the 10 on D be called 100, then the 1 on C will be 10,000, &c. This being well understood, it cannot escape notice, that against every number on D stands its square on C.

Thus, against 25 stands 625
against 30 stands 900
against 35 stands 1225
against 40 stands 1600

Reckoning the 10 on D to be 10.

EXAMPLE 6. *To extract the square root of a number.*—Fix the slider exactly as in the preceding example, and estimate the value of the lines D and C in the same manner; then against every number found on C, stands its square root on D.

EXAMPLE 7. *To find a mean proportional between two given numbers, as* 9 *and* 25.—Set the one number (9) on C, to the same (9) on D; then against 25 on C, stands 15 on D, the mean proportional sought.

For, 1 : 15 : : 15 : 25.

EXAMPLE 7. *To find the mean proportional between* 29 *and* 430.—Set 29 on C to 29 on D; and then 430 on C will either fall beyond the scale D, or it will not be contained on C. Therefore take the 100th part of it, and look for 4.3 on C, and against it on D stands 11.2, which being multiplied by 10, will be 112, the mean proportional required.

SLIT DEAL, a name for inch-and-quarter-inch deal cut into two leaves, or made into two boards.

SMOOTHING PLANE. *See* PLANE.

SNACKET, a local term for a kind of hasp for a casement.

SNIPE'S-BILL, a plane with a sharp arris for getting out the quirks of mouldings.

SOCKET-CHISEL, a strong chisel, used by carpenters, for mortising; used by the percussive blows of a mallet.

SOCLE, or ZOCLE, (from the Latin, *soccus*) a square piece, of less height than its horizontal dimension, serving to raise pedestals, or to support vases, and other ornaments. The socle is sometimes continued round a building, or an entire part of a building. It has neither base nor cornice.

SOFFITA, SOFFIT, or SOFIT, in architecture, any timber ceiling formed of cross-beams, or flying cornices, the square compartments, or panels of which, are enriched with sculpture, painting, or gilding.

The word is Italian, and signifies the same with the Latin *lacunar* and *laquear;* with this difference, that *lacunar* is used for any ceiling with square hollow panels, called *lacus;* and *laquear* for compartments interlaced with platbands, after the manner of *knots*, or *laquei*. Such are those in the basilicas and palaces of Italy, and in the apartments of the Luxemburg at Paris.

SOFFITA, or SOFFIT, is also used for the underside of the corona, or larmier, which the ancients called *lacunar*, the French denominate *plafond*, and we, usually, *the drip*.

SOFFITS, the under sides of the heads of apertures, or the parts of mouldings which may be projected upon a horizontal plane, by lines perpendicular from all points of the mouldings upon that plane. Several methods have already been described, under the article ENVELOPE. What is proposed under the present head, is to show the methods adopted by early writers, not with a view of exposing their errors, but in order to guard the student against erroneous principles.

Figure 1, No. 1 and 2, as also *Figure* 2, No. 1 and 2, are from Swan's *British Architect*, *Plate* I.—"*Figure* 1 shows the opening of a window in a straight wall: draw the lines, ranging with the splay of the jambs; where these meet, s at *a*, is the length of the radius for drawing the curvature of the soffit; then take the distance *a b*, transfer it from *c* to *d*, in *Figure* 2; then set your compasses in *c*, and draw the circular line *e d;* then set on the width of your soffit, and draw the external line; this, when bent to a semicircle, will range along with each part of the straight wall.

"*Figure* 2 represents the opening of a window, of the same width as the former, in a circular wall. The shadowed semicircle above (*Figure* 2, No. 1) shows the opening of the arch. The arch-line may be divided into any number of parts, as here, into twelve. Draw lines perpendicular from the base-line, through all these divisions of the line *h;* then, in *Figure* 2, No. 2, draw a circular line, as for a straight wall; and divide it into the same number of parts as the arch-line above *Figure* 2; then take the distances from the line *h* to the circular wall, and set them from the outside line in *Figure* 2, No. 2, as at 1, 2, 3, &c. to 12; then you will have the true curvature of your soffit, which, when bent to a semicircle, will, in every part, agree with a circular wall."

The following are from the *Carpenters' and Joiners' Repository*, by William Pain:

"*Figure* 3 is a circular soffit in flewing jambs. Draw the flewing of the jambs, *c d* and *e f*, to meet at the point *a;* then draw the arch *d f*, and divide the said arch into any

number of equal parts, the more the truer the work, and run these parts on the dotted arch-line figure; then draw a line from *a* to *g*, which is the soffit stretched out; then draw a dotted line from the centre, *a*, the parts of the arch-line, stretched out far enough to receive the parts taken from the chord-line to the inside of the wall, and set them on the soffit, stretched out, as 1, 2, 3, 4, 5, 6, 7, 8, and so on; which will give the edge of the soffit.

"*Figure* 5.—A is a circular soffit in a circular wall, which is flewing on the jambs, and square at top; which makes the soffit winding as well as flewing. Draw the flewing of the jambs till they meet at *o*. The outside-arch is a semicircle, the inside-arch a semi-ellipsis. On the transverse diameter draw the plan of the wall, and the chord-line *e d*, equal to the opening on the inside 1 *c*; then, on the chord-line, *e d*, draw the semicircle, whose diameter is equal to *e d*; then, on the same chord-line, draw the lesser semicircle to the outside opening; then draw the ellipsis, *e d*, whose height is exactly equal to the height of the lesser semicircle; then divide the greater semicircle into a number of equal parts, and draw dotted lines from these parts to the inside curve of the wall; then apply a rule from the point *o*, to where those lines meet the inside of the wall, and draw the black lines across the plan of the wall, which will give the width of the soffit at those places; then draw, with the centre *o*, the two arch-lines 1 *b*, *f g*, and on the arch 1 *b*, run the parts on the great circle; and, from the centre, *o*, to these parts, draw the black lines across the soffit, stretched out, as 1, 3, 5, 7, 9; then take off the parts between the great semicircle and the ellipsis, and set them on the lines drawn across the soffit, stretched out, as 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, and trace through these points, which will give the inside of the soffit; then take the width of the plan on those black lines, and set it on the soffit, stretched out, will give the line *g i f*, which is the width of the soffit."

The following are taken from the *British Palladio*:—"*Figure* 4 is a circular flewing soffit, in a circular wall: continue the flewing of the jambs, till they meet at *e*; then take the radius, *e o*, and draw the arch-line *b o*; then divide the greater and lesser arch into the same number of parts, as here into 8; this will do for a straight wall: as this plan flews circular, take half the distance of the chord-line of the lesser arch in the compasses, and strike the dotted arch which divide into four parts; then set them on the chord-line of *b o*, as 1, 2, 3, 4, and draw lines from them to the arch-line stretched out parallel to *e* 1; then take *d g*, the distance of the chord-line of the plan and the curve, and set it from *h* to *n*, on the line *k e*; then set the distances, 2, 3, 4, of the chord-line and curve-line, and set from the arch-line stretched out on the parallel lines, 2, 3, 4; trace through those points from *b* to *n*, and you have half the edge of the soffit. To get the breadth, make a section of the arch, as on the right of *Figure* 4, No. 1; draw the perpendicular lines, 1 5, 1 5, the distances of *m o* on the plan; then take the distances *o*, 2, 3, 4, set them on the perpendicular line to the right, as marked from 1 to 2, 3, 4, 5, at right angles, the distances from the chord-line of the great arch, 1 1, 2 2, 3 3, 4 4, trace through them, and you have one side of this section; for the smaller arch, proceed as before, and on the other perpendicular line, 5 1, of the distances, as figured, 5, 4, 3, 2, 0; from 0 to 1 draw the flewing line of the arch, at the crown; take that distance, and set it from *n* to *k* on the soffit; also, to the perpendicular line on the side of the plan, *m*, *n*, set the compasses in *m*, and strike out the side of the flew to *n*; divide the difference of the line 0 1, from the section to *n*, into as many parts as the great arch; then set off those parts with a small curve, respectively, from 2, 3, 4, 6, on the soffit; then with the parts 1, 2, 3, 4, on the greater dotted arch, cross them from *k*; trace through them, and you have half the soffit; mark them to the other side, and the soffit is complete.

"*Figure* 6 is a circular flewing and winding soffit, in a straight wall. Continue the flewing of the jambs till they meet at *a*; then draw the arch-line *b c*, and make the chords equal to the circumference of the lesser arch, on which set the parts it is divided into, 1, 2, 3, 4; divide the distance of the chord from the arch into five parts; draw a line from 3 to *b*, and mark where it cuts the perpendicular 4 at *d*; draw a line from *d* to 1, parallel to the chord-line; divide 1 2 into four parts; from two of them draw a line parallel to 1 *d*; mark where it cuts the perpendicular of 3, on the chord-line at *e*; draw another parallel line from the third mark, and mark its crossing the perpendicular of 2, on the chord-line at *h*; trace through the points *b*, *d*, *e*, *h*, 2, this gives one side of the soffit, then take the ordinates across the plan, 1 1, 2 2, 3 3, 4 4, and the side of the flew *a f*, and set them from 2, *h*, *e*, *d*, *b*; then take the parts 1, 2, 3, 4, of the greater arch, and set them from 1 to 2, 3, 4, *f*; trace through them, and get the other side; set off these; measure to the other half, and complete the soffit."

Plate II. *Figure* 1.—A soffit, from the *Practical House Carpenter*. No. 1, is the plan and section of the centre. No. 2, is the covering extended in plano. The author describes it thus: "*Figure* B the plan of a circular wall, wherein a circular door, or window, is to be fixed; to make a soffit to fit or stand on the plan, as *Figure* D; draw the base-line of the arch, or soffit, to touch the bow of the wall; divide the arch-line into twelve parts, and drop them down to the plan across it; then stretch out the arch, as 1 to 12, and draw the divisions at right angles from it; then take them from the base-line to the wall, as 1, 2, 3, 4, &c., and transfer them on the parts of the line stretched out, will give the edge of the soffit D."

Figure 2.—A cylindrical soffit, cutting obliquely through a straight wall, from the *Practical House Carpenter*. The author describes it thus: "*Figure* E is a soffit in a straight wall on flewing jambs: F the soffit stretched out; stretch out the arch, as *o* to 8, and draw lines from those divisions parallel with the jambs; then draw the lines from the divisions on each side of the plan; the angle of meeting will give the edge of the soffit." This description is imperfect: for the true method, see the article Envelope.

Figure 3.—A cylindrical soffit in a circular wall, from Pain's *Practical Builder*. The author describes it thus: "*Figure* A is a circular wall, which has a door or window, that stands flewing. Because the jambs do not stand at right angles with the diameter of the circle, find the curve-line of the soffit in this case; draw the chord-line or base-line, of the arch, *o* 9, at right angles with the jambs *o*, *h*, to touch the arch of the wall at *a*, and divide the arch into equal parts, and drop them to the wall; then take off the distances *h g*, 8, 9, 7, *f*, 6, *e*, &c., and put them on the arch stretched out, gives the edge of the soffit." It is singular, that this method should be true, while the former, which is more simple, is false.

Figure 4.—A cono-cuneoidal soffit in a circular wall. No. 1 is the plan and sections of the centre: No. 2, the soffit stretched out.

Figure 5.—A conical soffit in a cylindrical wall, where the aperture expands towards the concave surface of the wall.

Figure 6.—A conical soffit in a circular wall, where the aperture expands towards the convex surface of the wall.

Figure 7.—A cono-cuneoidal soffit in a circular wall, where the aperture expands towards the convex surface of the wall.

These *Figures*, viz., 4, 5, 6, 7, are from Pain's *Golden Rule*. The principles upon which they are founded are erroneous: see the article ENVELOPE; where are given correct methods for *Figures* 5 and 6, and very near approximations for *Figures* 4 and 7.

SOILS, an obsolete pronunciation for the sills of a window. *See* SILL.

SOILS, in roofing, in Westmoreland, are what are generally denominated in London, PRINCIPAL RAFTERS, which see.

SOLDERING, the method of uniting two or more metals by partial fusion. The union is effected by an alloy or solder, of greater fusibility than the metals to be united.

SOLID, (from the Latin, *solidus*, compact,) in geometry, a magnitude of three dimensions, extended in length, breadth, and thickness.

A solid is terminated, or contained, under one or more plain surfaces, as a surface is under one or more lines. From the circumstances of the terminating lines, solids are divided into *regular* and *irregular*.

Regular solids are terminated by equal and similar planes, so that the apex of their solid angles may be inscribed in a sphere. Under this class come the DODECAHEDRON, the ICOSAHEDRON, the OCTAHEDRON, and the TETRAHEDRON, or CUBE. See those articles.

SOLID ANGLE, an angle formed by three or more plane angles meeting in a point.

The sum of all the plane angles constituting a solid angle, is always less than 360°; otherwise they would constitute the plane of a circle, and not a solid.

If the apex of a solid angle be supposed in the centre of a sphere, the measure of the solid angle is the space intercepted upon the surface of the sphere by the planes of such angle.

Hence the comparison of solid angles is easily effected: for since the areas of spherical triangles are measured by the excess of the sums of their angles, each above two right angles, and the areas of spherical polygons of n sides by the excess of the sum of their angles above $(2n-4)$ right angles; it follows, that the magnitude of a trilateral solid angle will be measured by the excess of the sum of three angles above $(2.3-4=2)$ above two right angles; and the magnitude of solid angles, formed by n bounding planes, will be measured by the excess of the sum of the angles of inclination of the several planes above $(2n-4)$ right angles.

In all cases, the maximum limit of solid angles will be the plane, towards which various planes determining such angles approach, as they diverge farther from each other about the same summit; the same as a right line is the maximum limit of plane angles, being formed by the two boundary lines, when they make an angle of 180°. The maximum limit of solid angles is measured by the surface of the hemisphere, in like manner as the maximum limit of plane angles is measured by the arc of a semicircle.

The solid right angle is $\frac{1}{4}=(\frac{1}{2})^2$ of the maximum solid angle; while the plane right angle is half the maximum plane angle.

SOLID SHOOT. *See* WATER SHOOT.

SOLIVE, (French,) among carpenters, a joist, rafter, or piece of wood, either slit or sawed, with which the builders lay their ceilings. This word, though generally found in builders' dictionaries, is not used by English carpenters.

SORTANT ANGLE, the same as SALIENT ANGLE, which see.

SOSTRATUS, in biography, the most eminent architect of his time, was a native of Cnidos, in Lesser Asia, the son of Dexiphanes, also an architect, who flourished in the third century before the Christian æra. The high patronage he met with, caused him to be denominated *the friend of kings*. He was particularly in favour with Ptolemy Philadelphus, sovereign of Egypt, and is celebrated in history for the terraces, supported on arcades, with which he adorned his native city. He also built the celebrated lighthouse on the island of Pharos, opposite to Alexandria, which was reckoned among the wonders of the world; and, by a crafty device, he transmitted his name to posterity, in lieu of that of his patron. Being ordered to engrave upon the tower an inscription to the following effect: "King Ptolemy to the gods, the saviours, for the benefit of sailors;" instead of the king's name, he substituted his own, and then filling up the letters with mortar, he painted upon it as he had been directed; but in process of time, the mortar wearing out, the original engraving appeared, and the inscription ran, "Sostratus, of Cnidos, the son of Dexiphanes, to the gods, the saviours, for the benefit of sailors;" which remained as long as the tower stood.

SOUFFLOT, JAMES GERMAIN, an eminent architect, born, in 1714, at Irancy, near Auxerre. His father, an *avocat* of the parliament, destined him for his own profession, and sent him, while very young, to Paris for education; but preferring the science of architecture, he was for some time employed in that art at Lyons, whence he repaired to Italy, for improvement, and, on his return to France, was admitted one of the king's pensioners. It being resolved that several public buildings should be erected at Lyons, he was recommended to undertake part of the work, by the director of the French academy at Rome; and the construction of the Exchange and the Hospital was committed to him. The noble simplicity of the Hospital, together with its excellent adaptation to the object for which it was intended, were universally admired, and raised his reputation as an artist. After this, he was employed to build the Concert-Room and Theatre of the same city. He next travelled again into Italy, and on his return, settled at Paris, where he was successively made comptroller of the buildings at Marly and the Tuilleries, member of the academies of architecture and painting, knight of St. Michael, and intendant of the royal buildings. In 1757, he laid the foundation of the church of St. Geneviève, of which he only finished the portal, the nave, and the towers. In this business, he subjected himself to some severe criticism, especially with respect to the possibility of erecting the intended dome upon the basis designed for it; though some exact calculations justified his plan. The criticisms and unfriendly remarks of his rivals were more than his temper, naturally irritable, could bear; and he died partly of chagrin, in the year 1780, at the age of 67. Besides the public works already mentioned, he executed many others, which display the powers of a great genius; and after his death, M. Dumont, professor of architecture, published a book of designs, which he had left behind him, under the title of *Élévations et Coupes de quelques Edifices de France et d'Italie, désignées par feu M. Soufflot, Architect du Roi, et gravées.*

Though Soufflot was rough and hasty in his manners, he was kind and friendly, whence he obtained the name of *Le Bourru Bienfaisant.*

SOUND-BOARD, the same as a canopy or type over a pulpit, used for the purpose of increasing the sound by reflection.

SOUND-BOARDING, in floors, short boards placed transversely between the joists, and supported by fillets, fixed to the sides of the latter, for holding the pugging, which is any substance that will prevent the transmission of sound from one story to another. The narrower the sound-boards, the better. The fillets, on which the sound-boards rest, may be about three-quarters of an inch thick, and

about an inch broad, nailed to the joists at intervals of one foot each.

SPAN, the width of an arch; the distance between the piers, or the length of an imaginary line extending between its springing on either side; the same as *chord*.

SPANDREL, an irregular triangular space, bounded on one side by the outer or convex curve of an arch, and on the other two by two straight lines touching the curve, and meeting each other at right angles. It is commonly formed in Gothic architecture by an arch with a rectangular hood-mould, the spandrel so formed being frequently enriched with carving or sculpture, sometimes with foliage, at others with quatrefoils, shields of arms, and various devices.

The term is further applied to any surface of a similar form, or formed under similar circumstances.

SPANDREL BRACKETING, a cradling of brackets fixed between one or more curves, each in a vertical plane, and in the circumference of a circle, whose plane is horizontal.

PROPOSITION I.—*Given the plan of a square room to be covered or vaulted with spandrel bracketing, and the vertical section of the cove, whose plane passes through the axis of the room, and through the intersection of two adjoining walls; to find the figure of the springing on the walls, so that the faces of the brackets may be in the surface of a solid, formed by revolving the given section from its place in the angle, round the axis of the room, until it makes a revolution.*

In the given square inscribe a circle, which will represent the ceiling-line, from any angle of the square draw a line to the centre: apply the given section upon this line as a base, to its place at the angle. Take any number of points in the curve, and draw lines perpendicular to the base to cut it. Upon the centre of the square, and with the distance of the several points of section, describe arcs cutting any side of the square. From these points draw perpendiculars to that side, from which make the several lengths of the perpendiculars equal to those of the section; through the extremities draw a curve, which will be the figure of the springing.

Example 1. *Figure* 1.—Let the given square be A B C D, and let E be its centre; join E B; apply the given section, B F, to E B, as a base, so that when turned perpendicular round E B upon the square, it will then be in its place. In the curve, F B, take any number of points, *h*, and draw the lines *h i*, perpendicular to E B, meeting it at the point *i*. On the centre, E, with the radii E *i*, describe arcs, *i k*, meeting A B in the points *k*. From the points *k*, draw the lines, *k l*, perpendicular to A B; and also from M, the points of contact, draw M N. Make the perpendiculars M N, *k l*, *k l*, &c. equal to the lines *i h*: through the points B, *l*, *l*, *l*, &c., to N, draw a curve, which will be half the springing line required. But if the points *p* are taken in the arc, M G, equidistantly, and the points *p* be the upper ends of the brackets, it will be much more convenient to draw the lines E *p k*. On the centre, E, with the radii E *k*, describe the arcs *k i*; draw the perpendiculars *i h* and *k l*, and proceed as before, to complete the curve, as the points *l* will give the spring of the foot of the brackets. In this example, the section here given is a quadrant; but it may be any geometrical curve, or any other line, that fancy may suggest, the same method extending to all.

Example 2. *Figure* 2.—In this example, the section given is a part of a circle, the radius of which is half the diagonal of the square, therefore, the quadrant, one of whose radii is the axis, and the other the half of the diagonal, will generate a hemisphere. It is evident, that if a square be inscribed in its base, and cut by planes through the sides of the square at right angles to the base, the sections will be semicircles; therefore, upon any side, as a diameter, describe a semicircle, and it will give the springing required. The places or springing-points of the brackets, may be found as before.

PROPOSITION II.—*Given the plan of an oblong room, to be coved or vaulted with spandrel bracketing, the ceiling-line an ellipsis inscribed in the plan, and a section of the cove, through the diagonal perpendicular to the ceiling-line; to find the spandrels of the bracketing, such that they may be the intersections made by the planes of the four walls, with the curved surface of a solid, generated by the given section, moving always perpendicular to the ceiling-line, which passes through the upper extremity of the curve of the generating section, and the lower extremity, always in a horizontal plane.*

Figure 3.—Let the oblong, A B C D, be the plan of the walls, and E F G H, the inscribed ellipsis; E G being the greater axis, and F H the lesser, parallel to the sides of the rectangle; consequently, E, F, G, H, the points of contact. In any quadrant, E H, take any number of equidistant points, *i*, or rather in a ratio, in which every succeeding two towards E, the extremity of the longer axis, will be nearer and nearer together, by the property of the ellipsis. Draw the lines, *i k*, perpendicular to the curve, cutting the two sides, D A, D C, in the points *k*. Let N E O be the given section, N E its base, which is a prolongation of G E, the line drawn from D, perpendicular to the curve, meeting it at R; from the point E, on E N, make the distances E *l* respectfully equal to the lines *i k*. Draw the lines *l m* perpendicular to N E, cutting the curve N O in the points *m*, and the lines *k p* perpendicular to A D and D C: make all the lines *k p* equal to the lines *l m*, and through the points *p* draw curves, which will be half the springing line on the two adjacent sides, and the points *p* will be the places for the springing of the brackets. The reader must here observe, that though the points *l* would describe parallel curves on the horizontal plane, yet none of these curves would be ellipses.

PROPOSITION III.—*Given the plan of a rectangular room to be coved with spandrel bracketing, supposing the surface of the solid with which the faces of the brackets are to coincide, to be an ellipsoid, the base of the spandrel solid, a section passing through its axis, given the springing-line of one of the ends, which is a section perpendicular to the fixed axis; to find the springing-line upon the sides, so that they may be of the same height with that upon the ends, and also the curves of the ribs.*

Figure 4.—Let A B C D be the rectangular plan, and let A F B be the section given, which is necessarily semicircular; upon A D, as a transverse axis, and with one-half of A B, as a semi-conjugate, describe the semi-ellipsis A G D, and it will be the springing required for the other two sides. Produce I O and H P, the two axes of the inscribed ellipsis, in all the four directions. Through any point, A, in one of the angular points of the plane, describe an ellipsis, N K L M, whose two axes shall be on the lines H P and O I, and also in the same ratio as those lines, the transverse axis being M K, and the conjugate N L; this ellipsis would be the base of the ellipsoid. Now, as every section passing through the shorter axis of this ellipsoid, viz., all the vertical ellipses passing through E, have the same conjugate axis, it will be very easy to describe the ribs over any given seat, as this seat is the transverse axis, and the radius of the greatest circle is the semi-conjugate.

Two diagrams illustrative of the method of obtaining the projection of angle-brackets are added.

Figure 1, a cove bracket; B A E the plan of the angle-rib; the ordinates *h i*, are taken from the ordinates *g f*.

Figure 2.—Another cove-bracket, of which one side has less projection than the other. B G D, the plan of the angle, as before; the bracket A G B, the angle B G D, and the position of the line, G E, are given; H G E, being an obtuse angle, viz., the angle of the room. The ordinates, *m n*, of one side of the room, are taken from the ordinates, *k i*, of the given bracket, A B G.

SPAN-PIECE, a provincial term in Lincolnshire, and perhaps in other counties, for COLLAR-BEAM, which see.

SPAN-ROOF, a roof consisting of two inclined sides. The term is used in contradistinction to *shed-roofing*. Span-roofing may have simple rafters, with or without a collar-beam; or the roof may be trussed; in which latter case, the term applies only to the external construction.

SPECIES OF TEMPLES: these are determined by the number of columns in the front of the portico; which, with their distance from each other, is regulated by the diameter of the columns at the bottom. *See* TEMPLE.

SPECIFICATION, a detailed and formal description of an edifice to be erected, the materials to be used therein, and the particular uses to which they are to be applied. Specifications are provided for the guidance of the builder in making his tender for work, and are appended to the contract. They are usually divided into several heads, according to the different trades employed in the work, and ought to be made out with great accuracy and precision; the more simple they are, the better.

SPECIFIC GRAVITY, a comparison of every solid, or fluid, with the weight of the same magnitude of rain-water. Rain-water is chosen as the standard of comparison, on account of its being less subject to variation in different circumstances of time, place, &c., than any other body, whether solid or fluid. And by a very fortunate coincidence, at least to English philosophers, it happens, that a cubic foot of rain-water weighs 1,000 ounces avoirdupoise; and consequently, assuming this as the specific gravity of rain-water, and comparing all other bodies with this, the same numbers that express the specific gravity of bodies, will at the same time denote the weight of a cubic foot of each in avoirdupoise ounces, which is a great convenience in numerical computations.

From the preceding definition, we readily draw the following laws of the specific gravity of bodies, viz.,

1. In bodies of equal magnitudes, the specific gravities are directly as the weights, or as their densities.

2. In bodies of the same specific gravities, the weights will be as the magnitudes.

3. In bodies of equal weights, the specific gravities are inversely as the magnitudes.

4. The weights of different bodies are to each other in the compound ratio of their magnitudes and specific gravities.

Hence it is obvious, that if in the magnitude, weight, and specific gravity of a body, any two be given, the third may be found; and we may thus find the magnitude of bodies, which are too irregular to admit of the application of the common rules of mensuration; or we may, by knowing the specific gravity and magnitude, find the weight of bodies which are too ponderous to be submitted to the action of the balance or steel-yard; or, lastly, the magnitude and weight being given, we may ascertain their specific gravities.

Example 1.—*The weight of a marble statue being* 748*lb. avoirdupoise, required the number of cubic feet, &c., which it contains; the specific gravity of marble being* 2742.

Since a cubic foot weighs 2742 ounces, we have

as $2742 : 748 \times 16 : : 1 : 4.36$ feet.

Example 2.—*Required the weight of a block of granite whose length is* 63 *feet, and breadth and thickness each* 12 *feet; the specific gravity of granite being* 3500.

Here $63 \times 12 \times 12 = 9072$ feet: then again

as $1 : 9072 : : 3500 : 31752000$ ounces:

or 885 tons, $18\frac{3}{4}$ cwt. The above are said to be the dimensions of one of the stones in the walls of Balbec.

Other properties relating to the specific gravity of bodies are as follows, *viz.*

1. A body immersed in a fluid will sink, if its specific gravity be greater than that of the fluid; if it be less, the body will rise to the top, and be only partly immersed; and if the specific gravity of the solid and fluid be equal, it will remain at rest in any part of the fluid in which it may be placed.

2. When a body is heavier than a fluid, it loses as much of its weight when immersed, as is equal to a quantity of the fluid of the same bulk or magnitude.

3. If the specific gravity of the fluid be greater than that of the body, then the quantity of the fluid displaced by the part immersed, is equal to the weight of the whole body. And hence, as the specific gravity of the fluid is to that of the body, so is the whole magnitude of the body to the part immersed.

4. The specific gravities of equal solids are as their parts immersed in the same fluid.

5. The specific gravities of fluids are as the weights lost by the same immersed solid.

Hence are drawn the following rules for ascertaining the specific gravities of both solids and fluids.

To find the specific gravity of a body.—This may be done generally by means of the hydrostatic balance, which is contrived for the easy and exact determination of the weights of bodies, either in air, or when immersed in water, or other fluid, from the difference of which the specific gravity of both the solid and fluid may be computed.

1. *When the body is heavier than water.*—Weigh it both out of water and in water; then say,

As the weight lost in water
Is to the whole or absolute weight,
So is the specific gravity of water
To that of the body.

2. *When the body is lighter than water.*—In this case attach to it a piece of another body heavier than water, so that the mass compounded of the two may sink together. Weigh the denser body and the compound body separately, both out of the water and in it; and find how much each loses in the water by subtracting its weight in water from its weight in air; and subtract the less of these remainders from the greater. Then use the following proportion:

As the last remainder
Is to the weight of the light body in air,
So is the specific gravity of water
To the specific gravity of the body.

3. *When the specific gravity of the fluid is required.*—Take a piece of some body of known specific gravity; weigh it both in and out of the fluid, and find the loss of weight by taking the difference of these two; then say,

As the whole or absolute weight
Is to the loss of weight,
So is the specific gravity of the solid
To the specific gravity of the fluid.

The following table exhibits the specific gravity of several of the most common bodies; it is extracted from a more extensive one given in Gregory's *Mechanics;* and other tables of a similar kind will be found in the works of Emerson, Muschenbroeck, Ward, Cotes, Martin, &c.

Table of Specific Gravities of Bodies.

METALS.

Brass, cast, not hammered	8396	Mercury, solid or congealed	15632
——, cast, common	7824	——, fluent	13568
Copper, not hammered	7788	Nickel, molten	7807
Gold, pure, melted, not hammered	19258	Platina, crude, in grains	15602
——, the same hammered	19362	——, purified, not hammered	19500
——, guinea	17629	——, ditto hammered	20337
Iron, cast	7207	Silver, virgin, not hammered	10477
Iron rod	7700	——, ditto, hammered	10511
Steel, neither tempered nor hardened	7833	——, shilling	10534
——, hardened, but not tempered	7840	Tin, pure Cornish melted, and not hardened	7291
Iron ore, prismatic	7355	——, hardened	7299
Lead, molten	11352	Zinc, molten	7191
——, ore of, cubic	7587		

STONES.

Beryl	3549	Spar	2595
Chrysolite, of the jewellers	2782	Topaz	4011
Crystal	2653	Agate onyx	2638
Diamond	3521	Flint	2594
Emerald	2775	Jasper	2816
Garnet	4189	Opal	2114
Ruby	4283	Pearl	2684
Sapphire	3994	Pebble	2664
		Stone, paving	2416

VARIOUS STONES, EARTHS, &c.

Alabaster	2730	Glass, white	2892
Amber	1078	——, bottle	2733
Ambergris	926	Granite, red Egyptian	2654
Basalts, from Giant's Causeway	2864	Hone, white razor	2876
Bath Stone	1975	Limestone	3179
Brick	2000	Marble	2742
Chalk	2784	Phosphorus	1714
Clay	2000	Portland stone	2013
Coal	1269	Porphyry	2765
Earth, common	1520	Pyrites	4954
Gypsum, opaque	2168	Slate	2672
Glass, green	2642	Stone, common	2520
		Sulphur	2033

LIQUORS, OILS, &c.

Alcohol, commercial	837	Oil of turpentine	870
——, highly rectified	829	——, whale	923
Ether	720	Water, rain	1000
Beer	1034	——, distilled	1000
Milk, woman's	1020	——, sea	1026
——, cow's	1032	Wine, Port	997

RESINS, GUMS, &c.

Bees-wax	965	Honey	1456
Bone of an ox	1659	Ivory	1822
Camphor	989	Tallow	945
Gunpowder	930	Wax	897

WOODS.

Alder	800	Beech	852
Ash, the trunk of	845	Box, French	912
Cedar	596	Mahogany	1063
Cherry-tree	715	Maple	750
Cork	240	Oak, heart of, 60 years	1170
Ebony	1331	Pine, American yellow	460
Elder-tree	695	Poplar	383
Elm, trunk of	671	Vine	1327
Fir, red or yellow	550	Walnut	671
Fir, white	470	Willow	585
Larch	560	Yew, Dutch	788
Lignum-vitæ	1333	——, Spanish	807
Logwood	913		

GASES.

Atmospheric air	1.000	Light gas	986
Carbonic air	1.524	Nitrogen	672
Carbonic oxyde	967	Oxygen	1.106
Hydrogen	69	Pit gas	558

SPERE, a screen across the lower end of ancient halls.

SPHERE, (from the Greek, *σφαιρα, a ball,*) a solid, whose surface is everywhere equally distant from a certain point within the solid; which point is called *the centre of the sphere.*

Every sphere is equal to two-thirds of its circumscribing cylinder; that is, it is equal to a cylinder, whose ends are circles, equal to a great circle of the sphere, and whose height is equal to the diameter of the same. Therefore,

To find the solidity of a sphere. Multiply the square of the diameter by .7854, and this product by the diameter of the sphere, and take two-thirds of the last product; or,—Multiply the cube of the diameter by .5236, and the product is the solid content.

To find the superficies of a sphere.—Multiply the area of the great circle by .4, and the project is the superficies.

Example.—To find the solidity of a sphere, whose diameter is 23 feet, 3 inches.

Here 23 : 3=23.25 in decimals.

23.25
23.25

11625
4650
6975
4650

540.5625
23.25

27028125
10811250
16216875
10811250

12568.078125
.5236

75408468750
37704234375
25136156250
62840390625

6580.6457062500

The superficial content of the same sphere is 540.5625 + 4=2162.2500.

SPHERICAL BRACKETING, the forming of brackets to support lath-and-plaster-work, so that the surface of

the plaster shall form the surface of a sphere. *See* PLASTERING.

The form of the bracketing depends upon the planes in which they are disposed, within the surface of a sphere: but, in all cases, the edges are circular, because the section of a sphere is a circle, according to any position of the cutting plane: the edges of the bracketing will be equal circles, when their planes intersect each other in the centre of the sphere; in this case, the edges require no bevelling: but if the planes of the brackets are disposed in a parallel way, the edges are all unequal circles, and the edges, which receive the lath, will be more oblique, as the planes of the circles are more remote from the centre of the sphere: therefore, the quantity of labour, and the waste of timber, will entirely depend on the disposition of the planes of the bracketing.

SPHEROIDAL BRACKETING, the bracketing prepared for a plaster-ceiling, whose surface is to form that of a spheroid.

As all the sections of a spheroid are either circles or ellipses, the edges of the bracketing are either circles or ellipses.

As a spheroid may be supposed to be generated by the revolution of a semi-ellipsis upon one of its axes; therefore, if the planes of the bracketing be disposed in parallel planes, perpendicular to the axis of the generating circle, the edges of the bracketing must be circles.

If the planes of the bracket be disposed in planes passing through the axis of rotation, the edges of the bracketing will be portions of an ellipsis, equal and similar to the generating semi-ellipsis.

If the planes of the bracketing be so disposed as to pass through a diameter of the great circle of the spheroid, viz., that circle perpendicular to and bisecting the generating axis; then all the ribs of the bracketing will be elliptic quadrants, bounded by two semi-axes and the quadrantal curve; one of the semi-axes will be equal to the radius of the great circle, and the other will be found upon the plane of the generating ellipsis.

SPHINX, a sculptured figure frequently found in Egyptian temples, and their approaches, representing a monster with the head and breasts of a woman, the wings of a bird, the claws of a lion, and the other parts of the body like a dog.

SPIRAL, (from the Latin, *spira*, involved,) a curve which makes one or more revolutions round a fixed point, and which does not return to itself. *See* VOLUTE.

SPIRE, a pyramidal acutely-pointed covering or roof, most usually found on towers of churches and on turrets. Spires are constructed either of stone or of wood, covered with lead, slate, or oak shingles. They were probably not introduced into England till some time after the Norman conquest. In the earliest examples, they are usually of the same plan as the tower, either square, circular, or octagonal, and are of no very great height. In early English examples of later date, they are sometimes of the same plans, but more frequently octagonal, and also of much loftier proportions; where an octagonal spire stands on a square tower, the angular spaces left unoccupied are covered by pinnacles, or by semi-pyramidal masses of masonry sloping against the spire. The outline is frequently broken by one or more tiers of small open windows, termed spire-lights, the faces of which are vertical, and therefore project out at the top from the sloping face of the spire; they are usually covered with gablets or sharp pediments, which in the later and more ornamented styles are often enriched with crockets, finials, pinnacles, &c. Spire-lights are frequently placed on the alternate faces of the spire in alternate tiers. Early English spires are usually what are termed *broach-spires;* that is to say, they spring directly from the edge of the tower, without the intervention of a parapet, whereas, in the later styles, the parapet is seldom omitted. In the Decorated and Perpendicular styles, the spire is more enriched, usually having angular pinnacles, and often flying-buttresses from the pinnacle to the spire; crockets sometimes adorn the angles of the spire, and ornamental bands divide it into several stages. Spires are terminated at the apex either with a finial or metal cross or vane, the latter being frequently in form of a cock, as an emblem of prayer and watchfulness. Spires of open work are not unfrequent in the larger continental churches.

SPITAL, an hospital.

SPLAYED, (from the old French, *disployer*, to spread abroad,) a term, in architecture, applied to whatever has one side making an oblique angle with the other: thus, the heading-joints of a boarded floor are frequently splayed in their thickness, as are also the jambs, or sides, of a window; in the latter case, the room may be lighted to the greatest advantage. The word *fluing* is sometimes applied to an aperture in the same sense as *splayed*.

SPRING BEVEL OF A RAIL, the angle made by the top of the plank, with a vertical plane touching the ends of the rail-piece, which terminates the concave side.

SPRINGED, in boarding a roof, the art of setting the boards together with bevel-joints, so as to keep out the rain.

SPRINGING COURSE, the horizontal course of stones from which an arch begins to spring; or the row of stones upon which the first arch-stones are laid.

The term is also applied to the bottom stone of the coping of a gable.

SQUARE, (from the Latin, *quadratus*, having four corners,) a term among workmen, applied to any material, when two of the sides stand perpendicular to each other. In joinery, the work is said to be *square-framed*, or *framed square*, when the framing has all the angles of its styles, rails, and mountings, square, without being moulded.

SQUARE, an instrument for trying whether an angle be a right angle, generally consisting of an outer and inner square, parallel to each other; the former for trying interior angles, the latter for exterior ones.

SQUARE-SHOOT. *See* WATER-SHOOT.

SQUARE-STAFF, a piece of wood, used for fortifying the angles of plaster-work intended to be papered over.

SQUARING HAND-RAILS, the method of cutting a plank to the form of a rail for a staircase, so that all the vertical sections may be rectangles. The squaring is the most difficult part in the execution of hand-rails, as the moulding and finishing must be regulated by it. To perform it accurately, the plank must be shot to the proper bevel, or edge; then, supposing it to be set to the pitch, a vertical line must be drawn on the edge, and the face-mould must be applied, first on one side of the plank, so that the two points may come close to the edge that is shot, and, one of them coinciding with the vertical face, lines are to be drawn by the edges of the mould on the surface of the plank. The mould is then to be applied to the other side, in the same manner, and lines drawn as before; after which, the plank is to be cut out between the lines thus drawn on both sides, great care being taken to keep the teeth of the saw perpendicular. The edges will then only want smoothing, and the top and bottom of the rail-piece will be brought to a level by the falling mould. *See* HAND-RAILING.

SQUARING OF A PIECE OF STUFF, the act of trying it up by the square, in order to make the angles right angles.

SQUINCH, a small arch thrown across the angles of square towers to support octagonal spires. The same object is sometimes effected by corbelling out at the angles, which has this advantage over the arch, that it does not tend to thrust apart the walls of the tower; this latter plan is termed the straight squinch.

SQUINT, an opening often found in the walls of churches, passing through them in an oblique direction, usually on one or both sides of the chancel-arch, so as to enable persons sitting in the aisles or transept to see the elevation of the host: where there are no chancel-aisles, there is often a projection on the exterior of the church through which the aperture is pierced. In Bridgewater church, Somersetshire, the perforation is carried through three walls in an oblique line, so as to enable persons in the porch to view the altar.

Some of these openings extend from the ground to a heignt of ten feet, or thereabouts, but they are usually two or three feet above the ground, and two or three feet high, by two wide; they are frequently plain, but sometimes highly enriched. They are more correctly termed *hagioscopes.*

STABLE, a house or shed for horses and cattle generally.

STADIUM, a Roman measure of length, nearly equivalent to an English furlong. Also an enclosed area in which the various athletic exercises were exhibited.

STAFF-BEAD, a vertical piece of timber placed on the exterior angles of the walls of apartments to preserve the arris, which, if made up of plaster, is liable to be broken; it is frequently moulded with a bead on the outer edge.

STAINED GLASS, pieces of glass stained of various colours, and arranged so as to form a variety of patterns or devices, and sometimes of pictorial representations.

The ancient Egyptians are said to have made and coloured small ornaments of glass, but glass does not seem to have been much used by any of the ancients; small pieces are found in Roman mosaics, and some larger plates have been discovered at Herculaneum, which some have supposed to have been used as window glass. According to Bede, glass was employed in the windows of Bishop's Wearmouth church, but it did not come into general use for some time afterwards, and was not used in private houses till A. D. 1180. Stained glass for windows, was probably in use as early as the ninth century, but no example exists in England of earlier date than the twelfth century, to which period belong the remains at Canterbury. These consist of panels of various forms, containing subjects on a deep blue or ruby ground, the spaces between the panels being filled up with mosaic patterns in which ruby and blue are the prevalent colours; the whole is surrounded with a border of foliage and scroll-work.

During the Early English period, the glazing consists of panels, circles, quatrefoils, and other forms, including that of the vesica piscis, and these contain subjects; the spaces between are filled with coloured mosaic patterns, and the whole contained in a border of leaves and scroll-work. Sometimes the entire space within the border is filled with scrolls, and foliage, on a deep blue or ruby ground, the scrolls, &c., being either of coloured glass, or only in black outline in plain glass; in the latter case, panels formed by strips of coloured glass are sometimes inserted. Quarry glazing, in which the windows are formed by lozenge-shaped pieces of glass, with a small pattern upon each, is first used in this style.

In the Decorated style, quarry glazing becomes of frequent use, and the panel system loses ground; where panels occur, the ground is covered with patterns of foliage of a more flowing and natural character than in the preceding style; the vine and ivy leaves are favourites. Sometimes the entire window is filled with such foliage, which is often only in outline, and frequently only some portions of the pattern are stained yellow. Quarries contain small patterns of leaves, rosettes, &c., sometimes in plain outline, but frequently coloured yellow; in foliage patterns, in which the vine and ivy leaves predominate, the stalks of the leaves are often so arranged, as to form one continuous flowing pattern throughout the window, and at other times, one edge of each quarry had a coloured stripe, so that when put together they each appeared surrounded with a coloured border. The entire design is surrounded, in most cases, with a running border of foliage and flowers. At this period, single figures surmounted by canopies, begin to appear, at first of small size, two or more being contained in one light, but afterwards they become larger, and were disposed one in each light.

In the Perpendicular period, this practice begins to increase, the figures and canopies are of a larger size, more than one being seldom contained in one light; at last whole windows containing several lights were filled with one large grouped subject. Quarries still continue in use, but the devices do not flow one into the other, consisting mostly of rosettes, flowers, fleurs de lis, and heraldic devices, the latter being very frequently and generally adopted in this style. Coloured inscriptions on bands or scrolls are frequently seen running diagonally, and at regular intervals, across windows, from top to bottom.

With the decline of Gothic architecture, stained windows fell into disuse; and with its revival, it is now occupying a great deal of attention, and is executed with considerable taste and skill.

STAIRCASE, a term applied to the whole set of stairs, with the walls supporting the steps, leading from one story to another. The same staircase frequently conducts to the top of the building, and thus consists of as many stories as the building itself.

When the height of the story is considerable, resting-places become necessary, which go under the name of *quarter-paces* and *half-paces*, according as the passenger has to pass a right angle, or two right angles; that is, as he has to describe a quadrant or a semicircle. In very high stories that admit of sufficient head room, and where the space allowed for the staircase is confined, the staircase may have two revolutions in the height of one story, which will lessen the height of the steps; but in grand staircases only one revolution can be admitted, the length and breadth of the space on the plan being always proportioned to the height of the building, so as to admit of fixed proportions.

In contriving a grand edifice, particular attention must be paid to the situation of the space occupied by the stairs, so as to give them the most easy command of the rooms.

With regard to the lighting of a grand staircase, a skylight, or rather lantern, is the most appropriate; for the light, thus admitted, is powerful, and the design admits of greater elegance; indeed, where the staircase does not adjoin the exterior walls, this is the only method by which light can be admitted.

In small buildings, the position of the staircase is indicated by the general distribution of the plan; but in larger edifices, this is not so obvious, but must at last be determined by considering maturely its connection with the other apartments.

STAIRS, (from the Saxon, *stæger*,) in a building, the steps whereby to ascend and descend from one story to another.

The breadth of the steps of stairs in general use in common dwelling-houses, is from 9 to 12 inches, or about 10 inches at the medium. In the best staircases of noblemen's houses, or public edifices, the breadth ought never to be less than 12 inches, nor more than 18. It is a general maxim,

that the greater breadth of a step requires less height than one of less breadth: thus, a step of 12 inches in breadth will require a rise of $5\frac{1}{2}$ inches, which may be taken as a standard by which to regulate those of other dimensions; so that multiplying 12 inches by $5\frac{1}{2}$, we shall have 66; then supposing a step to be 10 inches in breadth, the height should be $\frac{66}{10}=6\frac{3}{5}$ inches, which is nearly, if not exactly, what common practice would allow. The proportions of steps being thus regulated, the next consideration is, the number requisite between two floors or stories, which will be ascertained by supposing the breadth of the steps given, say 10 inches each, as depending on the space allowed for the staircase, and this, according to the rule laid down, will require a rise of 7 inches nearly; suppose, then, the distance from floor to floor to be 13 feet 4 inches, or 160 inches: $\frac{160}{7}=22\frac{3}{7}$, which would be the number required; but as all the steps must be of equal heights, we should rather take 23 rises, provided the staircase-room would allow it, and so make the height of each somewhat less than 7 inches.

The most certain method of erecting a staircase is, to provide a rod of sufficient length to reach from one floor to the other, divided into as many equal parts as the intended number of rises; and try every step as it is set, to its exact height. The breadth of the staircase may be from 6 to 20 feet, according to the use or occupier of the building, or the form and proportions of the plan. If the steps be less than three feet in length, the staircase becomes inconvenient for the passing of furniture, as is frequently the case in small houses.

Though it is desirable to have such rules as are here laid down for regulating the proportions of the heights, breadths, and lengths of steps, architects and workmen cannot be so strictly tied to them, but that they may vary them as circumstances may demand.

Stairs, *Straight*, such as ascend in a straight line, and consist only of plane surfaces.

Stairs, *Winding*, those which turn round a solid newel, or circular well-hole; the latter either enclosed in a complete cylindric case, or semi-cylinder, at one end, adjoined to two parallel walls, which terminate upon an opposite wall.

In winding stairs the steps are formed narrower next to the well-hole than at the other end, where they adjoin the wall; these are termed *winders*.

Those steps which continue of the same breadth are termed *flyers*, in contradistinction to the winders.

A series, or number of flyers, connected together, is termed *a flight of steps*.

STALK, an ornament in the Corinthian capital, similar to the stalk of a plant, from which spring the volutes and helices; it is sometimes plain, and at others fluted.

STALL, (from the Saxon, *steal*, a shed,) a place, or division of a stable, for a single horse to stand and feed in.

According to the number of these divisions, a stable is denominated a *one-stall*, *two-stall*, &c. *stable*.

Stall, a fixed seat, enclosed entirely or partially at back and sides, and frequently in an elevated position; to be seen at the sides of the choir, or chancel of parish and cathedral churches, in the latter of which, they are frequently covered with a lofty and rich canopy, with tabernacle-work, and richly carved on the sides and back, as also on the desk in front. They are appropriated to the officials and dignitaries of the church.

STANCHION, a term applied to any perpendicular support, such as the mullions of windows, &c.; also to the upright iron bar between the mullions, which is frequently terminated by a finial, or other ornamental top.

Stanchions, or Puncheons. *See* Studs.

STANDARDS, (from the Saxon, *standan*, to be on the feet,) the upright poles used by bricklayers in scaffolding.

Standards, in joinery, the upright pieces of a plate-rack, commonly placed above a dresser. When the edges of standards are cut into mouldings across the fibres of the wood, they are called *cut standards*.

Standards: the term is applied generally to upright supports, or upright pieces which are used to keep other pieces together; thus the upright ends of stalls or benches, into which the back and seat are fixed, are termed standards.

STAPLE, (Dutch,) a small bar of iron, pointed at each end, and bent so that the two ends may be parallel to each other, and of equal lengths; to be driven into wood, or into a wall, so as to form a loop for fastening a hasp, or bolt.

STARLINGS, in bridges and similar works, are the projections in front of the piers, usually pointed or rounded off at the ends, and employed to break the force of the current, and protect the piers from iniury.

STAVES, (from the Saxon, *stæf*, a staff) in joinery, the boards that are joined together laterally, in order to form a hollow cylinder, cylindroid, cone, or conoid, or any frustum of these bodies. The shafts of columns, in joinery, are frequently glued up in staves.

Staves are also small cylinders sometimes called *rounds*, for forming a rack to contain the hay in stables, out of which the horses eat.

STAY BAR, the horizontal iron bar placed across windows, to strengthen the mullions.

STEEL, (from the Saxon *stal*,) is made of the purest malleable iron by an operation called *cementation*, by which it acquires a small addition to its weight, amounting to about the hundred and fiftieth, or two hundredth part. In this state it is much more brittle and fusible than before. It may be welded like bar-iron, if it has not been fused or over cemented: but its most useful and advantageous property is, that of becoming extremely hard when heated and plunged into cold water; the hardness which it thus acquires is greater, as the steel is hotter and the water colder. The sign that should direct the mechanic in the tempering of steel, is the variation of colour which appears on its surface. If the steel be slowly heated, it exhibits a yellowish white, yellow, or gold colour, purple, violet, or deep blue. If the steel be too hard, it will not be proper for tools intended to have a fine edge, as it will be so brittle that the edge will soon become notched: and if too soft the edge will soon turn aside, even by very slight use. Some artists heat their tools, plunge them into cold water, and then brighten the surface of the steel upon a stone; the steel being then laid upon hot charcoal, or upon the surface of melted lead, or on a bar or piece of hot iron, it gradually acquires the desired colour, and must at that instant be plunged into water. If a hard temper be required, as soon as the yellow tinge appears, the piece is dipped again, and stirred about in the cold water.

In tempering tools for working upon metals, it will be proper to bring them to a purple tinge before the dipping. Springs are tempered by bringing the surface to a blue tinge. This temperature is also desirable for tools employed in cutting soft substances, such as cork, leather, and the like; but if the steel be plunged into water when its surface has acquired a deep blue, its hardness will scarcely exceed the temperature of iron. When soft steel is heated to any one of these colours, and then plunged into water, it does not acquire so great a degree of hardness as if previously made quite hard. The degree of heat required tc harden steel varies in the different kinds. The best require only a low red heat; the harder the steel, the more coarse and granulated

will its fracture be. Hardened steel has less specific gravity than the soft. The texture of steel is rendered more uniform by fusing it before it is made into bars, and in this state it is called *cast steel*, which is wrought with more difficulty than common steel, because it is more fusible, and will disperse under the hammer if heated to a white heat.

Every species of iron is convertible into steel by cementation; but the best steel can be made only from iron of the best quality, which possesses stiffness and hardness as well as malleability. Swedish iron has been long remarked as the best for this purpose.

The *cast steel* of England is made as follows: a crucible, about ten inches high, and seven in diameter, is filled with ends and fragments of the crude steel of the manufactories and the filings and fragments of steel works; they add a flux, the component parts of which are usually concealed. It is probable, however, that the success does not much depend upon the flux. This crucible is placed in a wind furnace, like that of the founders, but smaller, being intended to contain only one pot, and surmounted by a cover and chimney to increase the draught of air; the furnace is then entirely filled with coke, or charred pit-coal. Five hours are required for the perfect fusion of the steel. It is then poured into long, square, or octagonal moulds, each composed of two pieces of cast-iron fitted together. The ingots, when taken out of the mould, have the appearance of cast iron. It is then forged in the same manner as other steel, but with less heat and more precaution. Cast steel is almost twice as dear as other good steel; it is excellent for razors, knives, joiners' chisels, and all kinds of small work requiring an exquisite polish: its texture is more uniform than that of common steel, which is an invaluable advantage. It is daily more and more used in England, but it cannot be employed in works of great magnitude, on account of the facility with which it is degraded in the fire, and the difficulty of welding it.

STEEPLE, a spire or lantern; the pyramidal roof of a tower. By some the term is made to include both tower and spire, and by others is used indifferently for any lofty tower, with or without a spire.

STENCH TRAP, a valve to prevent the emission of effluvia from drains and sewers; they are of various forms.

STEPS, (from the Saxon, *stæp*,) the degrees of a staircase, by which we rise, consisting of two parts, one horizontal, called *treads*, the other vertical, called *risers*. When steps are placed round the circumference of a circle, or of an ellipsis, or any segments of them, they are called *winders:* but when the sides are straight, they are called *flyers*. The first or lower step, with a scroll wrought upon its end, according to the plan of the hand-rail, is called *the curtail step*.

STEREOBATA, or STEREOBATES, (from στερεοβατης, *solid prop*,) in ancient architecture, the basis, or foundation, whereon a column, wall, or other piece of building, is raised. This answers pretty well to the continued socle, or basement of the moderns. Some confound it with the ancient *stylobata*, or *pedestal*; but, in effect, the stereobata is to the stylobata, what the stylobata is to the spire, or base of the column.

STEREOGRAPHIC PROJECTION OF THE SPHERE, is that in which the eye is supposed to be placed in the surface of the sphere.

STEREOGRAPHY, (from στερεος, *solid*, and γραφω, *to describe*,) that branch of solid geometry which demonstrates the properties, and shows the construction, of all solids which are regularly defined. It explains the methods for constructing the surfaces in plains, so as to form the entire body, or to cover the surface of a given solid; or, when a solid is bounded by plain surfaces, the inclination of the planes is determined by the rules of stereography. The sections of solids are also a branch of stereography; but this we shall refer to the article STEREOTOMY, with which it is more intimately connected.

Mr. Hamilton has denominated the principles of perspective by the name of *stereography;* but in this sense the term is too limited, as perspective is only a branch of the doctrine of solids, and extends only to the sections of pyramids and cones, and the representations of solids.

The eleventh and twelfth books of Euclid, which treat of the properties of solids, may be looked upon as the elements of this branch of geometry; and to them we shall refer our readers for the first elements to be acquired.

It is somewhat singular, that though the first principles of solids have long been demonstrated, no practical application to mechanical constructions has been made of them. The knowledge of solids is of the greatest importance in the constructive parts of architecture, as in masonry, bricklaying, carpentry, &c.

To be proficient in the art of construction, this branch of geometry is indispensable, and contains the very essence and foundation of the whole in abstract.

Definition 1.—*A solid* is that which has length, breadth, and thickness.

Definition 2.—The exterior surface of a solid is called its *superficies*.

Definition 3.—*A straight line* is perpendicular, or at right angles to a plane, when it makes right angles with every straight line meeting it in that plane.

Definition 4.—*A plane* is *perpendicular to a plane*, when the straight lines drawn in one of the planes, perpendicularly to the common section of the two planes, are perpendicular to the other plane.

Definition 5.—*The inclination of a straight line to a plane* is the acute angle contained by that straight line, and another drawn from the point in which the first line meets the plane, to the point in which a perpendicular to the plane drawn from any point of the first line above the plane meets the same plane.

Definition 6.—*The inclination of a plane to a plane* is the acute angle contained by two straight lines, drawn from any, the same point of their common section at right angles to it, one upon one plane, and the other upon the other plane.

Definition 7.—Two planes are said to have the *like inclination* to each other, which two other planes have, when the said angles of inclination are equal to one another.

Definition 8.—*Parallel planes* are such as do not meet each other, though produced.

Definition 9.—*A solid angle* is that which is made by the meeting of more than two plane angles, which are not in the same plane, in one point.

Definition 10.—*Similar solid figures* are such as have all their solid angles equal each to each, and contained by the same number of similar planes.

Definition 11.—*A prism* is a solid, of which the ends are similar and equal plane figures, and the sides parallelograms.

Definition 12.—When the ends of the prism are perpendicular to the sides, it is called *a right prism;* but if otherwise, it is termed *oblique*.

Definition 13.—A prism, whose sides and ends are equal squares, is called *a cube*.

Definition 14.—When the ends are parallelograms, the prism is called *a parallelopiped;* and when the planes of the parallelopiped are at right angles to each other, the prism is called *a rectangular prism*.

Definition 15.—When the ends of the prism are circles, it

is called *a cylinder;* but if the ends are ellipses, and alike situated, it is called *a cylindroid.*

Definition 16.—The straight line extended between the centres of the two bases is called *the axis.*

Definition 17.—A solid having any plane figure for its base, and its sides plain triangles terminating in the same point, is called *a pyramid.*

Definition 18.—A solid having a circle for its base, and terminating in a point, such that a straight line extended from any part of the circumference of the base to the terminating point may be in the surface of the solid, is called *a cone;* and the surface which lies between the circumference of the base and the terminating point, is called *the conic surface.*

Definition 19.—If the plane of a circle be supposed perpendicular to a given plane, with its circumference or edge upon that plane; and if there be a straight line standing on any other point perpendicular to the said plane; and if another straight line be made to move parallel to the plane on which the circle stands, so as always to touch the circumference and the straight line, beginning at any given point, and proceeding entirely round until it arrives at the same point; then the solid bounded by the circle, and the surface passed over by the straight line contained between the circumference of the circle and the straight line is called *a conoid;* and the surface generated by the straight line is called *a conoidal surface.*

Definition 20.—*A sphere* is a solid formed by the revolution of a semicircle upon its diameter.

Definition 21.—*The centre of a sphere* is the same with that of the semicircle.

Definition 22.—*The diameter of a sphere* is any straight line which passes through the centre, and is terminated both ways by the superficies of the sphere.

Definition 23.—*A cube* is a solid figure contained by six equal squares.

Definition 24.—*A tetrahedron* is a solid figure contained by four equal and equilateral triangles.

Definition 25.—*An octahedron* is a solid contained by eight equal and equilateral triangles.

Definition 26.—*A dodecahedron* is a solid contained by twelve equal pentagons, which are equilateral and equiangular.

Definition 27.—*An icosahedron* is a solid contained by twenty equal and equilateral triangles.

The solids defined in the last five definitions are called *the five regular solids.*

STEREOMETRY (from στερεομετρια, formed of στερεος, *solid*, and μετρον, *measure*,) that part of geometry which teaches to measure solid bodies, *i. e.*, to find the solidity, or solid content of bodies; as globes, cylinders, cubes, vessels, ships, &c. The methods see under the respective bodies; CYLINDER, GLOBE, SPHERE, &c.

STEREOTOMY, (from στερεος, *solid*, and τομη, *section*,) the science and art of cutting solids under certain specified conditions.

Stereotomy may be regarded as a branch of stereography, which is the science of solids in general. Mr. Hamilton has intitled his complete body of perspective, *Stereography*, which perhaps would have been more properly called *Stereotomy*, as the perspective representation of every object in nature is the section of a pyramid or cone of rays. But as it has not been the object of writers on perspective to show the rules for finding the sections of solids in general, under certain specified conditions of the cutting plane, nor of finding any other sections besides those of cones and pyramids, it is the express intention of this article to explain the general principles of the science for any given law, by which the surface of the solid may be constituted of straight lines, or that the surface may agree with the common section of two planes disposed in given positions. And as nothing of the kind has yet appeared, perhaps this attempt may be the more acceptable, particularly as in its principles the whole art of dialing is included, and the mechanical arts of masonry and carpentry. The art of stone-cutting, the squaring and cutting of timbers, and the formation of hand-rails, depend entirely upon the sections of solids.

Properties of Planes and Solids demonstrated in the eleventh book of Euclid's Elements, useful in Stereotomy.

Proposition I.—One part of a straight line cannot be in a plane, and another part above it.

Proposition II.—Two straight lines which cut each other are in one plane, and three straight lines which meet each other are in one plane.

Proposition III.—If two planes cut each other, their common section is a straight line.

Proposition IV.—If a straight line stand at right angles to each of two straight lines in the point of their intersection, it shall also be at right angles to the plane which passes through them.

Proposition V.—If three straight lines meet all in one point, and a straight line stands at right angles to each of them in that point, these three first straight lines are in one and the same plane.

Proposition VI.—If two straight lines be at right angles to the same plane, they shall be parallel to each other.

Proposition VII.—If two straight lines be parallel, the straight line drawn from any point in one to any point in the other, is in the same plane with the parallels.

Proposition VIII.—If two straight lines be parallel, and one of them at right angles to a plane, the other shall also be at right angles to the same plane.

Proposition IX.—Two straight lines which are each of them parallel to the same straight line, and not in the same plane with it, are parallel to each other.

Proposition X.—If two straight lines meeting each other be parallel to two others that also meet, but are not in the same plane with the first two, both couples will contain equal angles.

Proposition XI.—PROBLEM.—*To draw a straight line perpendicular to a plane, from a given point in space above the plane.*

Draw any straight line in the plane, and from the given point above the plane draw a second straight line at right angles to the first; from the point where the perpendicular meets the first line, draw a third straight line in the plane, at right angles to the first; and, lastly, from the given point in space draw a fourth line at right angles to the third; and the fourth straight line, thus drawn, will be perpendicular to the plane.

Proposition XII.—PROBLEM.—*To erect a straight line at right angles to a given plane from a given point in the plane.*

From any given point above the plane draw a straight line perpendicular to the plane, and through the given point in the plane draw a second line parallel to the first; which second line will be the perpendicular required.

Proposition XIII.—From the same point in a given plane there cannot be two straight lines at right angles to the plane, upon the same side of it; and there can be but one perpendicular to a plane from a point above.

Proposition XIV.—Planes to which the same straight line is perpendicular, are parallel to each other.

Proposition XV.—If two straight lines, meeting each other, be parallel to two other straight lines, which also meet,

but are not in the same plane with the first two; the plane which passes through the latter is parallel to the plane which passes through the former two lines.

Proposition XVI.—If two parallel planes be cut by another plane, their common sections with it are parallels.

Proposition XVII.—If two straight lines be cut by parallel planes, they will be cut in the same ratio.

Proposition XVIII.—If a straight line be at right angles to a plane, every plane which passes through it will be at right angles to that plane.

Proposition XIX.—If two planes cutting each other be each of them perpendicular to a third plane, their common section will also be perpendicular to it.

Proposition XX.—If a solid angle be contained by three plane angles, any two of them are greater than the third.

Proposition XXI.—Every solid angle is contained by plane angles, which together are less than four right angles.

Proposition XXII.—If every two of three plane angles be greater than the third, and if the straight lines which contain them be all equal, a triangle may be made of the straight lines that join the extremities of those equal straight lines.

Properties of Solids.

In a prism, all parallel sections which cut the sides, are similar and equal figures; or, all parallel sections which would cut the plane of the base, if produced, are similar and equal figures.

In a pyramid, all the parallel sections which are not parallel to the plane of the base, are unequal similar figures.

The properties of a cone are numerous and interesting. If cut parallel to the plane of the base, the section is *a circle;* if in any direction through the apex, the section is *a plane right-lined triangle;* if the cone be cut by a plane inclined to the plane of the base, at any given angle, the section is *an ellipsis;* if cut by a plane parallel to any straight line within the solid passing through the apex, the section is denominated *an hyperbola;* and if cut by a plane parallel to another plane which touches the curved surface, the section, formed by this position of the cutting plane, is called *a parabola.*

For the purposes of stereotomy, we shall suppose the cone a right one; and consequently the abscissa of the curves, or sections, will bisect all the double ordinates at right angles.

Definition 1.—If any semi-conic section be supposed to revolve upon its abscissa, so as to perform an entire revolution, the surface generated by the curve-line is called *a conoid*, and the abscissa *the axis.*

Definition 2.—If the semi-conic section be a semi-ellipsis, the solid generated is called *an ellipsoid.*

Definition 3.—If the generating figure be a semi-parabola, the solid is called *a paraboloid.*

Definition 4.—If the generating figure be a semi-hyperbola, the solid is called *an hyberboloid.*

Definition 5.—All solids whatever, generated by revolving plane figures upon an axis, are called *solids of revolution.*

Definition 6.—All parallel sections of conoids are *similar figures.*

General Principles of Construction.

Definition.—Solid angles, which consist of three plane angles, are called *trihedrals.*

In the construction of trihedrals, besides the three plane angles which form the boundaries of the solid, there are the three inclinations. These inclinations are, by way of distinction, called *the angles;* the three boundaries are called *the sides;* and the sides and angles are indifferently called *parts;* any three of which, excepting the three angles, may be found by the following constructions:

PROBLEM I.—*In a right-angled trihedral are given the two sides containing the right angle; to find the acute angles, and the side or hypothenuse which subtends the right angle.*

Figure 1.—Make the angle E B H equal to one of the given sides, and the angle E B F equal to the other; draw E H perpendicular to E B, and E I perpendicular to B F, cutting B F at F; from B, with the radius B H, describe an arc, cutting E I at I, and join B I; then B I is the hypothenuse: from E, with the radius E F, describe an arc, cutting E B in G, and join G H; then E G H is the angle contained by the hypothenuse and the side E B F, or the angle opposite the side E B H: or, make F I equal to G H, and join B I.

In the same manner the angle opposite the side of E B F may be found.

The reason will appear thus: raise the plane of the triangle B E F upon B E, so as to be perpendicular to the plane B E H; raise the triangle E G H upon E H, until E G fall upon E F; then the plane E G H will become perpendicular to B F; revolve the plane B I F upon B F, and F I will describe a circle, whose plane is also perpendicular to B F, from the point F; therefore, the plane of the circle and the plane E G H will be both in the same plane: therefore, since the point F coincides with G, the straight line F I may be made to coincide with G H; let this coincidence take place; and because F I is equal to G H, and the point G falls upon F, the point I will fall upon H; therefore, the straight line B I will fall upon B H; and the angle F B I, joining F B and B H, is the hypothenuse.

Again, it is evident from the planes thus raised, that the angle, E G H, contained by the planes F B E and F B I, and perpendicular to F B, their common intersection, is the measure of the angle contained by the planes F B E and F B I.

PROBLEM II.—*Given one of the sides containing the right angle and the angle opposite; to find the remaining side which contains the right angle.*

Figure 2.—Let the given side be H B E: in B E take any point, F, and make E F H equal to the angle required; draw H E perpendicular to E B; from E, with the radius E F, describe an arc, F G; draw B G a tangent at G; and E B G is the side required. The demonstration is evident from the last.

PROBLEM III.—*Given one of the sides containing the right angle and the inclination or angle adjacent; to find the remaining side which contains the right angle.*

Figure 2.—Make A B D equal to the given side; in A B take any point, E; draw E G perpendicular to B D, cutting it in G, and E H perpendicular to A B; make E F equal to E G, and E F H equal to the given angle; draw B H C, and A B C will be the measure of the plane angle opposite.

The following propositions show the construction of all the cases of trihedrals or spherical triangles, which are represented by right-lined angles. In each of the cases it will be found, that two of the sides of the spherical triangle are represented by the tangents of the arcs drawn from the same angle; and the angle included by these tangents is the measure of the spherical angle. The representation of the third side is a line joining the extremities of the tangents; the other two angles are measured by this proposition. If each of the three plane angles be denominated *a side*, and each of the three inclinations *an angle*, the geometrical construction will be the same as that of a spherical triangle, and the manner of expressing the data of the one is the same as expressing those of the other. The sides are always measured by the three plane angles of the solid angle.

PROBLEM IV.—*Given two sides and the contained angle; to find the other parts.*

Figure 3.—Make the angle A B C equal to the contained angle; draw B D perpendicular to A B, and B E to B C; make B D and B E equal to each other, the angle B D A equal to one of the containing sides, and B E C equal to the other

upon C, as a centre, with the distance C E, describe an arc, F; and upon A, as a centre, with the distance A B, describe another arc, cutting the former at F; join F A and F C; then the angle A F C will be the measure of the third side. Now if the triangle A B D be turned round the line A B, the triangle C B E round C B, and the triangle A C F round A C, until the points D, E, F, coincide, each of the two planes, A B D and C B E, will be perpendicular to the plane A B C; therefore, two of the sides of a solid angle will be given, one perpendicular to the other, to find the inclination of the vertical plane with that of the hypothenusal. Proceed, therefore, as in the last problem, and find the angle G H K, which will be the inclination of the two planes C B E and C A F. In the same manner may the inclination of the planes A B D and A C F be found.

Note.—The triangle A B C represents the spherical triangle, of which A B and B C are the tangents of two arcs; and the angle A B C is the spherical angle contained by the arcs, of which A B and B C are tangents.

Problem V.—*The three sides of a spherical triangle being given; to find the angles.*

Figure 4. No 1 and 2.—Make the three angles, A B C, C B E, and E B F, equal to the three sides of the spherical triangle, that is, to contain the same number of degrees. On B, as a centre, with any radius, A B, describe an arc, A F; draw A C and F E tangents at A and F; join C E; draw the straight line G H equal to C E; on the centre G, with the tangent A C, describe an arc at I; and on the centre H, with the tangent F E, describe another arc, cutting the former at I. Join G I and H I; draw I K and I L perpendicular to I G and I H, making them equal to A B or B F; join K G and L H. Now if the triangles, G I K and H I L, be raised on the lines G I and H I, until the points K and L coincide; then each of the triangles, G I K and H I L, will be perpendicular to the triangle G I H. Proceed, therefore, as in the first Proposition, to find the angles, which, in the representation of the spherical triangle I G H, are represented by G and H.

Scholium.—Since each of the extreme angles may be made the middle angle in No. 1, the triangle G H I, No. 2, may be laid down in three different figures, each of which will have as many angles included by each pair of tangents. These three angles, made in each separate triangle, are the measures of the three spherical triangles; but this mode requires more lines than what are described in the above Proposition.

There is another method of finding the angles of a spherical triangle, when the three sides are given, pointed out by Bishop Horsley, at page 215 of his *Elementary Treatises.* The substance of it is as follows: Draw a right angle; make one of the legs equal to the difference of the cosines of the sides containing the required angle; the hypothenuse being equal to the chord of the third side. Upon the remaining perpendicular side, as a base, construct a triangle, whose two other sides are equal to the sines of the sides containing the required angle; then the angle contained by the sines will be the measure of the spherical angle. This may be very easily accomplished by means of a scale of sines and chords from Gunter's scale.

Problem VI.—*Two angles and a side opposite to one of them, being given; to find the other two sides and the remaining angle.*

Figure 5.—Make the angle A B C equal to the spherical angle next to the given side; draw B D and B E perpendicular to B A and B C; make B D of any length, and B E equal to it; and make the angle B D A equal to the measure of the given side; draw A F perpendicular to B C, cutting it in F; make the angle F A G equal to the complement of the other given angle; on the centre F, with the distance F G, describe an arc, G H I; draw C H E a tangent to the arc at H, the same as in the second Proposition; join A C; and the angle C E B will be the measure of the included side. On the centre C, with the distance C E, describe an arc at K; and on the centre A, with the distance A D, describe another arc, cutting the former at K; join A K and K C; then will A K C be the measure of the third side of the spherical triangle.

Problem VII.—*Given two angles, and the contained side; to find the other three parts.*

Make A B C, *Figure* 3, one of the given angles; draw B E perpendicular to B C; make B E C equal to the number of degrees contained in the given side; in B C take any point, G; draw G I perpendicular to C E, cutting it at I, and G K perpendicular on the other side of it; make G H equal to G I, and the angle G H K equal to the other given angle; draw C K A, as in Proposition III., and A B C will be a plane triangle representing the spherical one.

Now, because A B C is the angle included by the tangents draw B D perpendicular to B A, and equal to B E, and join D A, then B D A is the measure of the side, of which A B is the tangent. On the centre A, with the distance A D, describe an arc at F; and on the centre C, with the distance C E, describe another arc, cutting the former at F. Join F A and F C; then A F C will be the measure of the third side.

Problem VIII.—*Two sides, and an angle opposite to one of them, being given; to find the three remaining parts.*

Figure 6.—Draw A C, representing the side adjoining the given angle, and A B perpendicular to it; make the angle A B C equal to the given side; in A C take any point, E; draw E D perpendicular to B C, cutting it in D, and E G perpendicular to A C; make E F equal to E D; and the angle E F G equal to the given angle; draw the line C G H; on A, as a centre, with the tangent of the other given side, describe an arc, K H; and if it cut the straight line C H in two points, H and K, join A K and A H; draw A I perpendicular to A H, and equal to A B; join I H; on the centre H, with the distance H I, describe an arc at M; and on the centre C, with the distance C B, describe another arc, cutting the former at M; join H M, K M, C M; then the angle C A K, or C A H, will be the measure of the spherical angle included by the tangents. The measure of the angle A H C, or A K C, representing the spherical angle opposite the given side, shown by the tangent A C, is found by Proposition I. The angle C M H, or C M K, is the measure of the remaining side, viz., that opposite the angle included by the tangents.

Note.—This case is not always ambiguous; for if A H be equal to, or greater than A C, the arc K H will only cut H C in one point; and, therefore, there can only be one triangle; or, if the angle A H C be a right angle, A H will only touch H C: and in this case also there can be only one.

Problem IX.—*The three angles of a spherical triangle being given; to find the three sides.*

Take the supplements of each of the angles, and describe a triangle, by Proposition V., whose sides are equal to such supplements; and the measure of its angles will be the supplements of the sides of the triangle sought. This is demonstrated by writers on spherical trigonometry.

Though the author of this Dictionary has not given formal demonstrations of the preceding Propositions relating to the geometrical construction of spherical triangles, as it would have swelled the article too far, he hopes that enough has been said to enable any one, who has a clear conception of the parts of a spherical triangle, to describe the representation of it, and to find the measure of its parts in the most easy manner, without having recourse to the projection of the sphere, which frequently runs into conic sections, and, from their difficulty of description, renders the projection

very inaccurate. The representation of the spherical triangle belonging to the preceding Propositions, is nothing else than a plane triangle, which is a tangent to the sphere at one of the spherical angles, and whose sides are bounded by the intersections of the planes of the three great circles of the sides of the spherical triangle; consequently, two of the sides of the representative triangle are always two tangents from the same spherical angle. The included angle by these tangents in the representative triangle is the measure of the spherical angle contained by the sides which the tangents represent. And the third side in the representative triangle is a line joining the extremities of the tangents, as has been already mentioned. In another point of view, the whole may be conceived to be a pyramid, whose sides are planes from the centre of the sphere, passing through the three arcs of the spherical triangle; and its base a triangle, a tangent to the sphere at one of the angles, which meets the sides. The vertical angles of the sides of this pyramid are the measures of the sides of the spherical triangle: the angles of the pyramid are the measures of the spherical angles: and the base of the pyramid is the representative triangle. Consequently, one of the angles of the pryamid is always perpendicular to the base. The angle intercepted by the two planes upon the base is equal to the inclination of the planes.

The triangle belonging to the preceding Propositions is such, that when all the parts are completed, the sides may be turned up upon the base, which is the representative triangle, until the edges of all the triangles forming the sides are united in one common vertex. A pyramid will then be formed, equal, similar, and situated like that above.

The Rev. George Walker, in his ingenious doctrine of the sphere, Proposition I. p. 258, shows, that "if there be a spherical triangle, and a plane quadrilateral figure be formed, two of whose sides are the secants, the other two the tangents of two of the sides of the spherical triangle, and the angle comprehended by the secants be measured by the spherical base, the angle comprehended by the tangents shall be the measure of the spherical angle opposite the base; the diagonals of the quadrilateral shall intersect each other at right angles; the segments of the diagonal joining the angle of the secants, and the angle of the tangents shall be the secant and tangent of the spherical perpendicular, drawn from the vertical angle to the base; the angle which this diagonal makes with the secants, shall be measured by the spherical segments of the base; and the angles which this diagonal makes with the tangents, shall be the measures of the spherical angles which the perpendicular makes with the sides." This theorem is very analogous to Problem V.; but the properties shown by it do not apply to the construction from any given data, nor can all the parts be found from any one datum; they may be very well applied when two sides and the contained angle are given, or when the three sides are given, by varying the triangle, as has been here shown, in order to find the other two angles; but this is both troublesome and inelegant. From what has been said, it will be easy to construct any solid similar to any other solid given, whose sides are planes, by constructing each solid angle, that is, by dividing it into as many solid angles, each consisting of three plane angles, wanting two, as the number of plane angles bounding the whole solid angle; then completing the figure of any side, of which a plane angle of the described solid angle is one similar to the side of the solid given. From the several angles of this figure construct other solid angles in the same manner.

Problem X.—*Given the seat,* A B, *of the intersection in space of two planes, having a given inclination, and the intersection,* A C, *of one of them in a given plane,* Y; *also the inclination of the common intersection of the two planes to the plane* Y; *to find the intersection of the other plane with* Y.

Figure 7.—Make B A D equal to the inclination of the intersection of the two planes; from any point, D, draw D E perpendicular to A D, cutting A B at E; make E B equal to E D; draw E C perpendicular to A B; make the angle C B F equal to the inclination of the planes, of which the seat of their intersection is A B; let B F meet E C in F; and join A F; then will A F be the intersection required.

Or thus: Through any point, E, in A B, draw C E perpendicular to A B; make E A D equal to the inclination of the intersection; draw E D perpendicular to A D; make E B equal to E D; join B C; make the angle C B F equal to the inclination of the planes, which have A B for the seat of their intersection; let B F meet C E in F; and join A F; then will A F be the intersection required.

Demonstration.—Imagine the triangle A D E to be turned upon A E, until it becomes perpendicular to the plane, Y; let the plane Z be turned upon C E, until E B fall upon E D; that E B will fall upon E D is evident, since E B, in revolving upon E C, will always be in a plane passing through E perpendicular to C E; and E D is also in a plane passing through E perpendicular to C E; and since E B is equal to E D, E B must fall upon E D, and the point B upon D; and the plane A E D will be perpendicular to the two planes C E A and C E B; therefore A D will be perpendicular to the plane C E B; whence it is manifest, that C B F is in a plane perpendicular to the common intersection, and is the measure of the inclination of the planes.

Problem XI.—*Given,* I N, *the intersection of a plane,* W, *with another plane,* X, *and their inclination, the seat,* A B, *in the plane,* X, *of a line in space insisting at* A, *and the inclination of the line to the plane* X; *to find the section of the line in the plane* W.

Figure 8.—Through any point, B, in A B, draw B S perpendicular to I N, cutting I N at E; make the angle B E F equal to the inclination of the plane; draw B G perpendicular to B S; make B G the tangent of inclination to the radius A B; draw G F parallel to B S; through A, draw any two lines, A J and A K, cutting I N at J and K; make E S equal to E F; through S, draw V L parallel to I N; produce B S to P; make S P equal to F G; draw P V parallel to A K, and P L parallel to A J; and join K V and J L, cutting each other at *a*; and *a* will be the section of the line in the plane W, as required.

For, imagine the triangles B E C and C G F in the same plane to be turned upon B E, so that their plane may be perpendicular to the plane X; then B G will be perpendicular to the plane X, and the point G will fall in the line in space: imagine also the plane W to be revolved upon I N, until E S falls upon E F, as is evident for the same reasons as given in the first Problem, and the point S will fall upon F; then the line V L will become parallel to the plane. In revolving the plane W upon I N, imagine the plane Y to revolve upon V L at the same time, so that the plane Y may always continue parallel to the plane X, then V P will continue parallel to A K, and L P parallel to A J; then, as in perspective, X is the original plane, W the plane of the picture, Y the vanishing-plane, G or P the place of the eye coinciding therewith, I N the intersecting line, V L the vanishing-line, J, K, the intersecting points, V L the vanishing-point, and the original line would be a visual ray; therefore, by the theory of perspective, *a* is the representation of the point A.

Problem XII.—*The same things being given, and the constructive lines remaining as in the preceding Problem, as also the point a, the section of the line in space; to find*

the seat of the line in the plane W, *and its inclination to the said plane.*

Figure 9.—Draw G Q perpendicular to E F, meeting E F in Q; in E P, make E T equal to E Q, and join T *a*; draw T R perpendicular to *a* T; make T R equal to Q G, and join R *a*; then will T *a* be the seat of the line in the plane W, and T *a* R its inclination to the said plane.

Demonstration.—For when E S is made to coincide with E F, as in the last Problem, the plane F C G will be perpendicular to the plane of the section W; but the line F C being now in the plane W, and Q G being perpendicular to F C, Q G will also be perpendicular to the plane W; but the point G, that is R, is a point in the line, whose seat is A B, and the point *a* is another point in the line, whose seat is A B; therefore, R and *a* are two points in the line, whose seat is A B; then join *a* R, which will be the part of the line in space on the other side of the plane W, and *a* T its seat.

Scholium.—This amounts to the same as when the seat and distance of the eye are given with respect to the original plane, and the position of a point in the said plane; to determine the seat and inclination of the visual ray.

PROBLEM XIII.—*Two straight lines,* A B *and* C D, *tending to an inaccessible point, being given; through a given point,* E, *to draw a third straight line, to tend to the same inaccessible point.*

Figure 10.—From any point, A, in A B, draw a straight line, A E, from A to the given point E, cutting C D in C; and through any other convenient point, B, draw B F parallel to A E, cutting C D in D; find D F, a fourth proportional to A C, C E, B D, and join E F; then will the lines A B, C D, and E F, tend to the same point of concourse.

Scholium.—It sometimes happens, that a number of lines radiate from the same point, and that from a given point it is required to radiate other straight lines so as to meet the radiations given in a given straight line: some, or many, of these radiations, according to their number, will be inaccessible; and though they may be all found by this Problem, yet if the several operations are combined in one, much trouble will be saved.

Figure 11.—Thus, let the radiations be A B, A C, A D, A E, A F, tending to the straight line B C; and let *a* be a given point, from which it is required to radiate other straight lines to meet or tend to the same points in B C, with those drawn from A. Join A *a*, cutting B C in G; and through any convenient point, C, in B C, draw F *f* parallel to A *a*; make C P equal to G A, and C Q in B C, produced to *o*, equal to G *a*; join P Q; let A D, A E, meet C F in D and E; draw D *m*, E *n*, F *o*, parallel to P Q, cutting R *o* at *m*, *n*, *o*; make C *d* equal to C *m*, C *e* equal to C *n*, C *f* equal to C *o*; draw *d a*, *e a*, *f a*, which are the lines required.

Example 1.—*Given the meridian,* A B, *in the plane of the horizon,* X, *the latitude of the place, the intersection,* I N, *of the plane,* W, *with the horizontal plane,* X, *and the inclination of the plane,* W, *to that of the horizon* X; *to construct a dial in the plane* W.

Figure 12.—In A B, take any point, A, for the foot of the style; then A B will be the seat of the style, or of the line tending to the pole; the latitude of the place is its inclination. Find *a*, the representation of A, that is, the section of the style of the dial in the plane W, by the eleventh Problem; produce A B to meet I N in D; draw D *a* in the dial plane W; then, by the twelfth Problem, find *a* T, the seat of the style in the plane W, and the angle of elevation T *a* R: and by the tenth Problem, find the intersections, U *a*, Y *a*, Z *a*, &c., of planes passing through the style, making angles respectively of 15°, 30°, 45°, 60°, &c., with the vertical plane passing through the meridian, A B; that is, with the plane whose intersection is T *a*: the inaccessible lines are also found by the last Problem; and the dial is constructed as required: *a* T is the seat of the style, whose intersection is T *a*; T *a* R its inclination; *a* D is the 12 o'clock line; and U *a*, Y *a*, Z *a*, &c., are the hour-lines.

Another method of finding the sub-style is thus: produce G Q to meet P E in H; join H A, which produce to N; and draw N *a*, the sub-styler line. Thus, upon one common principle, the sections of lines, planes, and solids, may be found. The sections of solids are found by means of the sections of planes; and the construction of a dial is only finding the sections of planes, whose positions are given. This method is, perhaps, of all others the easiest to consider and to construct.

Example II.—*Given the base,* A N Q R, *of a pyramid, in the plane* X, *and the whole seat,* A B, *of one of its angular lines, the intersection,* I N, *of the cutting plane* W, *and the inclination of the planes* W *and* X; *to find the section of the pyramid.*

Figure 13.—Find the vanishing line, V L, of the plane X, and the vanishing points, V and L, of the lines A R, N Q, A N, R Q; produce A R to K, N Q to M, A N to J, and R Q to L, to meet the intersecting-line I N; join K V and M V, also J L and L L; then *a n q r* will be the section of the pyramid insisting upon A N Q R.

Example III.—*To find the section of a prism, the same things as before being given.*

Figure 14.—Find the vanishing points, V and L, of the lines A J and A K, and the representations, K V and J L, as before; draw L *r* parallel to J L, and M *n* parallel to K V; and *q n a r* will be the section of the prism required.

Plate 3. *Figure* I.—*To find the section of a right pyramid.* Suppose a trahedral, or solid angle, consisting of three plane angles, two of which are at right angles to each other; let the base of the solid be disposed in one of the planes which form the right angle, and let the cutting plane be the plane angle which subtends the right angle; let *x*, or G P F, be the plane angle on which the base of the solid is to be placed; Y, or *g* P G, the other plane angle, standing perpendicular to the plane X; and *g* P *f*, or Z, the hypothenusal plane angle; the three angles being developed, or unfolded, upon one plane. Here P F will be the intersection of the cutting plane with the plane of the base. In the plane X, let A B C D be the base of the pyramid parallel to the intersection, E P; find the centre, E; produce A D from each extremity, to meet P F in F, and P G in P; through E draw H I parallel to A D, or B C, meeting P F at H, and P G at I; produce B C both ways, to meet P F at K, and P G at L; draw E N parallel to A B, meeting P G at N; produce A B to meet P G at M, and D C to meet P G at O; draw I Q and N R, each perpendicular to P G, and in length equal to the height of the pyramid; join G Q at L Q; also O R and M R; let P *g* be cut by G Q in *g*, I Q in *i*, L Q in *l*, O R in *o*, N R in *n*, and M R in *m*; transfer P F, P H and P K, to P *f*, P *h*, and P *k*; join *f g h i*, *k l*; parallel to P *f*, draw *m a* and *o d*, cutting *f g* at *a* and *d*, and *k l* at *b* and *c*; then the quadrilateral *a b c d* will be the section required.

Figure 2.—*To find the section when the base of the pyramid is oblique.*

Let A B C D be the base; find the points *g*, *i*, *l*, and F, H, K, as before; produce A B and D C to meet O F at M and N; transfer O F, O H, O K, O M, and O N, to O *f*, O *h*, O *k*, O *m*, O *n*, draw the diagonal B D, and produce it till it meet O F in T; transfer O T to O *t*, and produce O G and B D to meet each other; from the point of section draw a line, in the plane Y, perpendicular to O G, cutting O *g* produced; join *t* with the point of section; also join *g f*, *i h*, and *l k*, and let *g f* and *l k* cut the

line drawn from *t* to the point of section in o *g* produced; join *b m* and *d n*; produce *m b* to meet *f g* at *a*, and let *d n* meet *l k* at *c*; then will *a b c d* be the section required.

Figure 3.—*To find the section of a right cone.*

Let the circle A B C D E F G H be the base. Find the centre of the circle, and draw through it G V, parallel to I O, cutting O P at V, and the circumference at G and C; through the same point draw R L, perpendicular to I O, cutting I O at L, O P at R, and the circumference at A and E; divide the quadrants A C, C E, F G, G A, into any number of equal parts, as two, through the points of division draw lines parallel to G V and R L; one on each side of, and parallel to A E, cutting O P in Q and S; and the other parallel to G C on each side of it, cutting O P in U and W; draw R Y at Z, each equal to the height of the cone; draw P Y, Q Y, S Y, T Y, cutting o *p* in *p*, *q*, *r*, *s*, *t* respectively; also draw T Z, U Z, X Z, W Z, cutting o *p* in *x*, *w*, *u*, *t*; make o *i*, o *k*, o *l*, o *m*, o *n*, respectively equal to O I, O K, O L, O M, O N; join *p i*, *q k*, *r l*, *s m*, and *n t*; draw *x a*, *w h*, *v g*, *u f*, *t e*, parallel to o *i*, cutting *r l* at *a* and *e*; *k q* at *f* and *h*, and *m s* at *b* and *d*; then *a b c d e f g h* will be the section required.

Figure 4, shows how the section of an oblique cone is found; the method is the same as for a right cone: except that the intersection, B C, must be placed parallel to the inclination; by which means the axis, G I, has the same inclination to B C, which the axis has to the plane of the base.

Plate 4, is exceedingly useful in finding the bevels of the stones of oblique cylindric arches, where the joints of the stones run in planes perpendicular to the axis of the cylinder.

We shall here begin with the most simple case, which is *figure* 2. Let A B represent the axis of the cylinder, and let B C represent the plane of the arch; draw A D perpendicular to A B, and make the angle, D A E, equal to the inclination of the bed of a stone with the horizon; from the centre, A, with any radius, A E, describe the arc E D. Draw E C and D F parallel to A B, and C F parallel to A D; join E F; then if A B be the under-side of the joint or bed in the intrados of the arch, the angle, A B F, will be the angle which the under-side of the joint makes with the face of the arch.

Figure 4.—Exhibits the bevels for a complete arch, consisting of seven joints.

Figure 1.—Shows the method of finding the joints when the plane of the sides of the arch are not perpendicular to the horizon. Let A B represent the axis of the cylinder as before, B C the insisting-line of the side of the arch: produce B C to F; draw F G perpendicular to F C; make the angle, G F I, equal to the inclination of the end of the arch, and the plane of the horizon.

Figure 3.—Shows the joints for a complete arch.

Plate 5. *Figure* 1.—Exhibits the method of finding the section of a cone upon the general principles, as explained in *Plate* 2 of this article.

Figure 2.—The lines for the section of a cylinder.

Figure 3.—The lines for the section of a cuneoid.

Figure 4.—Another method for finding the section of a cone, which is plain to inspection, the principles being nearly the same as before.

Figure 5.—Section of a right cone.

Figure 6.—Section of an oblique cylinder.

Figure 7.—Section of a right cylinder.

Figure 8.—Method of the intersection of a plane from three given points, and the heights upon these points.

Figure 9.—Method of finding the section of the segment of a cylinder.

The principles and methods for these having been previously explained, it is presumed that, by barely inspecting the figures, the methods of tracing them will be sufficiently obvious without having recourse to the references of the letters.

Plate 6. *Figures* 1, 2, and 3.—Method of finding the section of a right prism when the plane of the section is perpendicular to one of the sides of the prism.

Figures 4, 5, and 6.—Method of finding the section of a right prism when the plane of the section is oblique to one of the sides of the prism, according to three given heights. *See* CYLINDER.

STERLINGS, *see* STILTS.

STILES, (from the Saxon, *stigele*,) in joinery, the vertical parts of a frame, into which the ends of the rails are fixed by mortises and tenons.

STILTED ARCH, an arch whose springing-line is above the impost, or which is raised, as it were, upon upright stilts or props.

STILTS, (from the Saxon *stælean*, supporters,) a set of piles driven into the ground-plot for the intended pier of a bridge; the tops of which being sawn to the low-water mark, the pier is raised upon them; a method formerly used, when the bottom of a river could not be laid dry. The stilts were surrounded, at a few feet distance, by a row of piles, with planks laid close to them, after the manner of a coffer-dam; this was called a *sterling*, or *jettee*; after which, loose stones, &c., were thrown into the space till it was filled up to the top; so as to form a kind of pier of rubble, or loose-work, which was kept together by the sides of the sterlings: the piling was then paved level at the top, and the arches were turned upon it. Most of the large old bridges in England were erected upon this method; but the inconveniences attending it are so great, that it is now quite exploded; for, on account of the loose composition of the piers, they must be made very large and broad, otherwise the arch would pusn them over, and fall down as soon as the centre was drawn. This great breadth of the piers and sterlings necessarily contracts the water-way so much, as not only to incommode the navigation through the arch, from the fall and quick motion of the water, but it also causes the bridge itself to be in danger, particularly in time of floods; besides this, there is great danger of the pier bursting out the sterlings, which are also subject to decay and damage, from the velocity of the water, and the passing of craft through the arches.

STOCK, (from the Saxon *stoc*,) a boring instrument, consisting of a double crank, so that one end may rest against the workman's breast, and the other upon the wood intended to be bored. It is provided with several steel cutters, called *bits*, of different dimensions, according to the holes to be made. It is, therefore, in London, called *stock and bits*, but in most country places, *brace and bits*.

STONE, (from the Saxon *ston*,) a hard mineral substance, not soluble in water, employed in the construction of edifices; of these there are various kinds, as described more largely under the article MATERIAL.

STONE ARCH, an arch constructed of stone: the general principles of the construction of which will be found under the article MASONRY.

STONE BRIDGE. In a former article, (BRIDGE) a general historical view has been taken, of the rise, progress, and present state, of bridge-building, exemplified in descriptions of the most celebrated edifices of the kind, in various parts of the world. Under the present head, the theory of the art will be principally considered; and we shall avail ourselves of the permission granted to us by the late Thomas Telford, Esq., to make considerable extracts from the able article on this subject, written by him for the Edinburgh Encyclopedia.

"The construction of a magnificent stone bridge, is justly

looked upon as one of the greatest performances of the masonic art: for if we compare the enormous weight of a great arch, with the strength which the cohesion of the firmest cement can give, we readily admit, that it is only by the nicest adjustment and balancing of its parts, that they are hindered from instantly falling to pieces.

"Though there can be little doubt that the Romans, and latter Greeks, had paid some attention to this subject, from the beautiful specimens of their architecture which exist even in our times; yet, in none of their authors, either practical or scientific, is the smallest light afforded us respecting the principles upon which their practice was regulated.

"The architects of the middle ages, who constructed those great cathedrals, that are still the ornament of the chief cities in Europe, and the delight of the architectural antiquary, seem to have fondly indulged in the balancing of arches. They were, without doubt, directed by maxims which had been elicited from a varied and extensive practice; but whatever these were, they are to us unknown. None of these architects, though many of them were men of learning, seem ever to have committed to writing, either the history of any such erection, or the principles by which its construction was regulated. Nay, this knowledge seems rather to have been carefully kept secret, and regarded as a sort of mystery; a craft which was only to be communicated to the *brethren*, whose experience and skill had already qualified them to be initiated into the mysteries of the sublime degree.

"It does not appear that a knowledge of this subject could be acquired otherwise than by experience. The mathematical sciences were then little known, and we may see from the construction of the bridges of that age, that the priests, who were the only architects, have had in their eye, rather, the successive vaulting of a Gothic cathedral, than to have originally considered of the best way of forming a permanent and convenient road. It was only about a century ago, when Newton had opened the path of true mechanical science, that the construction of arches attracted the attention of mathematicians. Since that time, volumes have been written respecting the equilibrium of arches. It has been found one of the most delicate, as it is one of the most important, applications of mathematical science. Yet with all due deference to the eminent men who have prosecuted this subject, we are much inclined to doubt whether the greater part of their speculations have been of any value to the practical builder. He is still left to be guided by a set of maxims derived from long experience, and, as yet, little improved by theory. In truth, his works seldom fail, even where they differ furthest from the deductions of the theorist; and at all events, he finds that a much greater latitude is allowable than theory seems to warrant. He is therefore surely excusable in doubting of the justice of such theories, at least until they are more consonant to the approved practice.

"It is our intention, in the present article, to point out a new mode of considering this subject, to which, with great diffidence, we request the attention of the intelligent practitioner. It may indeed still be deficient, if not in some respects erroneous, but it will, we think, have this merit, that of being readily apprehended, and easily applied, without requiring much previous scientific information. Indeed, though we highly value the sublime geometry, we are inclined to think that the unnecessary parade of calculus in the application of science to the arts, has been one of the chief causes of the dislike which many able practical men of our country have shown to analytical investigation.

"Nevertheless, as many of our readers are well qualified to comprehend, and will naturally expect that we should point out, the modes of investigation usually pursued in this interesting subject, we shall previously, and in as succinct a manner as possible, endeavour to lay before them the commonly received theory of equilibration. From which, having cleared away the useless rubbish, if we can extract any proper materials, we may, like economical builders, make good use of them in our future structure.

"The first thing like a principle that we meet with is the assertion of the eminent Dr. Hook, that the figure into which a heavy chain, or rope, arranges itself, when suspended at the two extremities, being the curve commonly called the *catenaria*, is, when inverted, the proper form for an arch; the stones of which are all of equal size and weight.

"Now, as this idea, strictly just, has been very generally adopted, and affords some useful hints, it may be well worth while to examine it.

"*Figure* 1.—Let A B be a string or festoon of heavy bodies, hanging by the points A, B, and so connected, that they cannot separate although flexible. These bodies having arranged themselves in the *catenaria* A C B, conceive this to be turned exactly upside down. The bodies A and B being firmly fixed, then each body in the arch A D B, being acted on by gravity, and the push of its two neighbours, with forces exactly equal and opposite to the former, must still retain its relative position, and the whole will form an arch of equilibration.

"This arch, however, would support only itself; nay, a mere breath will derange it, and the whole will fall down. But if we suppose each spherule to be altered into a cubical form, occupying all the space between the dotted lines, the stability will be more considerable. And as the thrust from each spherule to its neighbour is in a direction parallel to the tangent of the arch at the point of junction, it is obvious, that the joints of our cubical pieces must be perpendicular to that, so as to prevent any possibility of sliding.

"Our arch is now composed of a series of truncated wedges, arranged in the curve of the *catenaria*, which passes through their centres; and we are disposed, with David Gregory, to infer, that when other arches are supported, it is only because in their thickness some *catenaria* is included.

"This curve is, indeed, the only one proper for an arch consisting of stones of equal weight, and touching in single points, but is not at all adapted to the arch of a bridge, which, independent of the varying loads that pass over it, must be filled up at the haunches, so as to form a convenient road-way. In this case, some further modification becomes necessary.

"*Figure* 2.—The haunch, E, of the arch A C B, bearing a much greater depth of stuff than the crown, it must be so contrived as to resist this additional pressure. Every variation of the line F G H, or extrados, will require a new modification of the curve A C B, or intrados, and the contrary. Accordingly, M. De la Hire has suggested a good popular mode of investigating this subject. Let it be required to determine the form of an arch of the span A B, and height C D, proper for carrying a road-way of the form F G H. Mark off upon a vertical wall, the points A, C′, B, inverting the required figure: suspend from A B an uniform chain or rope, so that its middle may hang a little below the point C′, and dividing the span, A B, into any number of equal parts, and drawing the perpendiculars *a b*, *c d*, &c., suspend from the intersections, *e*, *f*, bits of chain, *e b*, *f d*, &c., so trimmed, that their ends may fall on the line of the road-way; and it may be observed, that as those pieces, which hang near the haunch, will bring it down, the crown, C′, will thereby be raised into its proper position.

"But although this mechanical way of forming an equilibrated arch be founded upon principles sufficiently just, and be perhaps the simplest and best way in which the practical

builder could form the original design of such an arch; yet as it affords no general rules that may be applied to the construction of arches, we proceed to consider the same subject in a mathematical point of view.

"*Figure* 3.—And first, then, in the semicircular polygon, as it is called, where weights are hung on the thread A c′ c c″ B, which bring it into the position A c B, we have at each angle three forces in equilibrio. Wherefore, by the principles of statics, they are to one another as the sines of the opposite angles; that is, the tension r c is to the tension l c, as sine l c w is to sine r c w, but the tension from c to l is the same as from c′ to r. Also, sine l c w is the same as sine r' c′ w′, since these angles are supplementary, c w, c′ w′ being parallel; therefore the tension r c is to the tension r' c′ as sine r' c′ w′ to sine r c w. *Or, the tension in each part of the chord is inversely as the sine of its inclination to the vertical.*

Again, we have as sin. d c l : sin. r c l : : tension r c : tension d c $= \frac{r \text{ c} \times \text{sin. } r \text{ c } l}{\text{sin. } d \text{ c } l}$; but as r c is inversely as sine r c d, therefore tension d c is as $\frac{\text{sin. } r \text{ c } l}{\text{sin. } r \text{ c } d \times \text{sin. } d \text{ c } l}$. Now, let an unlimited number of weights be hung from the chord, indefinitely near each other, and our polygonal thread becomes a curve; *Figure* 4 being in fact the curve of equilibration adapted to the weight which depends from it. The angles r c d and l c d become r' c d and l' c d, which are supplementary, and have equal sines, wherefore the product of these sines is the square of either. Also, as the sine of r c l or r c r' is as the curvature, or reciprocally as the radius of curvature, we have tension d c, or weight on c, inversely as rad. curv. × sin.^{2} inclination to vertical.

"This tension, in the present case, is usually produced by the gravity of the superincumbent materials, and may be measured by the area contained between two indefinitely near vertical lines E F, $e f$, *Figure* 4; but while the distance E e is constant, the area F e will diminish with the sine of F E e, as E e becomes more upright. To countervail this, we must enlarge the depth E F in the same proportion as sine e E F diminishes. And, therefore, we have E F inversely as rad. cur. × sin.^{3} F E e. *That is, the height of the superincumbent matter must be inversely as the radius of curvature, into the cube of the sine of the inclination of the curve to the vertical.*

"Let us proceed to apply the theory to some practical cases.

"If the arch be the segment of a circle, then the radius of curvature is the same throughout, and the height will be inversely as the cube of the sine of inclination to the vertical. And from this we derive the following very simple construction, for describing the equilibrating extrados of a circular arch, and which the reader, who has examined this subject, will find much easier than those commonly given.

"*Figure* 5.—At any point, D, draw the vertical D d, and D F from the centre C; then laying off D a equal to the thickness at the crown, draw the perpendiculars a b, b c, c d successively, D d is the vertical thickness at D, or d is a point in the extrados.

"For it is evident, that D a : D b : : D b : D c : : D c : D d, because of similar triangles; therefore, D a : D d : : rad. : sec.^{3} a D b, or inversely as radius to cube sine a b D. Now D a is the thickness at crown, and D d is therefore the thickness at D. *Figure* 6 is constructed in this way, and may serve as a specimen of the equilibrating extrados for a semicircular arch. By reversing this operation, we may find the thickness at the crown corresponding to a given thickness at any other point. And here we may observe, that as D, *Figure* 5, approaches the extremity, B, of the semicircle, the line D d rapidly increases, until, at the point B, it is of an infinite length. But indeed this must evidently be the case with every arch which springs at right angles with the horizontal line; for the thrust of the arch should be resisted by a lateral pressure, and no vertical pressure can act laterally on a vertical line.

"We may also observe, that since the extrados or upper outline descends first on each side of the crown, and then ascends with an infinite arc, there is, for any thickness of the crown, a point on each side where the upper edge of the extrados is on a level with that on the crown. Thus, if B D = 30°, its sine is half the radius. D a is therefore = $\frac{1}{8}$ of D d, so that if v v = D a be made $\frac{1}{14}$ of v C, the radius, we have the point d at the same level with v. Between this point, however, and the crown, there is a considerable depression, which is increased if the crown be made still thinner. On the other hand, if it be made thicker, the horizontal line drawn through the crown cuts the extrados much nearer the middle of the arch. It appears, therefore, that the circle is not well adapted for the purposes of a bridge, or a road, where the roadway must necessarily be nearly level; for no part of the extrados of the circular arch will coincide with the horizontal line. There is, indeed, a certain span, with a corresponding thickness at the crown, where the outline differs least from the horizontal; that is, an arch of about 54 degrees, with a thickness at the crown about $\frac{1}{4}$ of the span. But that is far too great for practical purposes.

"We may, however, extend the construction just given, even to those arches that are formed of portions of circles, differing in curvature. For the equilibrating extrados being first constructed for that portion of the arch in which the crown is, as far as the vertical line passing through the contact of the neighbouring curves, the thickness of the crown must be supposed to be enlarged, in proportion to the diminution of the radius of curvature, or the contrary, and, with this, proceed as before along the succeeding branch of the curve. This will, indeed, cause an unsightly break in the extrados, for which we shall not at present pretend to find any other remedy, than using materials of a different specific gravity.

"Those who wish to examine this subject farther, may consult Emerson's *Fluxions*, or Hutton's *Principles of Bridges*. We shall only observe here, that the extrados of the ellipsis, and of the cycloid, resemble that of the circle, having an infinite arc on each side at the springing; and indeed this, as has already been observed, is a general rule for all those curves which spring at right angles to the horizon. In the parabola the extrados is another parabola exactly the same, only removed a little above the other. In the hyperbola, the extrados is another curve, which approaches the interior arch towards the springing. None of these curves, therefore, can, with propriety, be employed for the arches of a bridge, though there may be cases where a single arch might, with propriety, be formed into a conic section.

"Mathematicians finding the circle, and other common curves, so little adapted to the arch of a bridge which has a horizontal roadway, have, in the next place, endeavoured to solve the converse of the problem, and give a rule for finding the intrados, or figure of the arch, which has the exterior curve a horizontal line.

"This problem can only be resolved by calling the fluxionary calculus to our aid. It is a case of the more general one to find the intrados when the extrados is given; and being the most useful case of that problem, fortunately admits of a solution comparatively easy.

"*Figure* 7.—We have already seen, that the load, D C, is

inversely as rad. curv. × sine³ inclination to vertical. Calling, therefore, as usual, the abscissa V E = x, C E = y, V C = z, we have C f = $\dot{x}$, f c = y, C c = $\dot{z}$; and since C c : C f : : rad. : sin. inclin. at C; therefore the load D C is inversely as rad. curv. × $\frac{\dot{y}^3}{\dot{z}^3}$. But as is well known, the rad. of curvature = $\frac{\dot{z}^3}{\dot{y}\,\ddot{x} - \dot{x}\,\ddot{y}}$; therefore, by multiplication, D C is inversely as $\frac{\dot{y}^3}{\dot{y}\,\ddot{x} - \dot{x}\,\ddot{y}}$, that is, directly as $\frac{y\,\dot{x} - x\,\dot{y}}{\dot{y}^3}$, or as $d\left(\frac{\dot{y}}{\dot{x}} \div \dot{y},\right)$ and is equal to $d\left(\frac{\dot{y}}{\dot{x}} \times \frac{c}{\dot{y}},\right)$ where c is a constant quantity, found by taking the real value of D C at the vertex, v, of the curve.

"Now, in the present case, calling A V = a, we have D C = $a + x$, (A V + V E,) therefore $a + x = \frac{c}{\dot{y}} \times$ flux. of $\frac{\dot{y}}{\dot{x}}$. Take $\frac{\dot{x}}{\dot{y}} = u$, and by integrating, we have $u = \sqrt{\frac{a\,2x + x^2}{c}}$, and therefore $y = \left(\frac{\dot{x}}{u} =\right) \sqrt{c} \times \frac{\dot{x}}{\sqrt{2ax + x^2}}$; whence, by integration,

$y = \sqrt{c} \times$ Lo. $(2ax + 2x^2 + 2\sqrt{2ax + x^2}) +$ B. At the vertex $x = 0$, therefore $y = \sqrt{c} \times$ Lo. $(2a)$. And consequently the ordinate $y = \sqrt{c} \times$ Lo. $\frac{a + x + \sqrt{2ax + x^2}}{a}$.

"Lastly, to find the value of $\sqrt{c}$, we take some point of the extrados, where the ratio of x and y is known. For example, if the span, = 2 s, and height, = h, are given, we have s = $\sqrt{c} \times$ Lo. $\frac{a + h + \sqrt{2ah + hh}}{a}$,

hence $\sqrt{c} = s \div$ Lo. $\frac{a + h + \sqrt{2ah + hh}}{a}$,

and, finally, $y = s \times \frac{\text{Lo. } \frac{1}{a}(a + x + \sqrt{2ax + x^2})}{\text{Lo. } \frac{1}{a}(a + h + \sqrt{2ah + h^2})}$.

"We subjoin a table, calculated by Dr. Hutton from this formula, for an arch of 100 feet span and 40 feet rise, the thickness of the crown being taken at 6 feet. It is nearly of the same dimensions as the middle arch of Blackfriars Bridge, and which may answer for any arch where these dimensions are similarly related to each other.

EC.	DC or AE.	EC.	DC.	EC.	DC.
0	6.000	21	10.381	36	21.774
2	6.035	22	10.858	37	22.948
4	6.144	23	11.368	38	24.190
6	6.324	24	11.911	39	25.505
8	6.580	25	12.489	40	26.894
10	6.914	26	13.106	41	28.364
12	7.330	27	13.761	42	29.919
13	7.571	28	14.457	43	31.563
14	7.834	29	15.196	44	33.299
15	8.120	30	15.980	45	35.135
16	8.430	31	16.811	46	37.075
17	8.766	32	17.693	47	39.126
18	9.168	33	18.627	48	41.293
19	9.517	34	19.617	49	43.581
20	9.934	35	20.665	50	46.000

"The curve of *Figure* 7 is accurately drawn to these dimensions, and may give an idea of the form of an equilibrated arch. It is not destitute of grace, and is abundantly roomy for craft.

"Such, then, is the analytical theory of equilibration: for a practical subject it does, we confess, appear abstruse.

"Let us turn, therefore, to another mode of considering this subject, which has been adopted by De la Hire, Parent, Belidor, and many others on the continent, and in our own country by the ingenious Mr. Atwood.

"The latter has, from the known properties of the wedge, and the elementary laws of mechanics, exhibited a geometrical construction for adjusting the equilibration of arches of every form.

"*Figure* 8.—The wedge A, if unimpeded, would descend in the direction V O, but is prevented by the reaction of B and B′, acting in the direction P Q and K I, perpendicular to the sides A G, Q D; and it is known, from the properties of the wedge, that if P Q, or K′ I, be to the weight of the wedge A, as D O is to D G, the wedge A will remain at rest. If also the wedge A be only at liberty to slide down G A, considered as a fixed abutment, then the force P Q alone will keep it in equilibrio. The force P Q being perpendicular to D O, has no tendency to make A slide either up or down on that line, but produce it towards N, making N M equal to P Q, then this force acting obliquely at N, may be reduced to two others, viz., M R perpendicular to A G, expressing the perpendicular pressure on the abutment of A, and R N expressing the force or tendency it has to make A slide upwards along A G. Again, take the vertical line A a, expressing the weight of A, and draw a H at right angles to A G; it is very evident, that A H expresses the tendency of A by its weight to slide down G A. A H is opposite, and is equal to N R.

"For, draw the perpendiculars D d and A p, then the triangles A a H, A G p, D G d, are evidently similar; and also the triangles O D d, O Q N, M N R, as they have always a common angle besides the right angle. Now, the force P Q, that is, M N, is to the weight of A, that is A a, as O D to D G, by supposition;

"And, A a : A H : : A G : A p : : D G : D d;

"Therefore, M N : A H : : O D : D d : : M N : N R.

"Or M N has the same ratio to A H, that it has to N R; that is, A H and N R are equal; or the tendency of A to slide downwards by its weight, is balanced by the tendency of M N to make it slide upwards; wherefore the section A remains at rest in equilibrio.

"Considering the whole arch as completed, with its parts mutually balancing each other, the force P Q, which is necessary for sustaining the wedge A, will be supplied by the reaction of the adjacent wedge B. Now, let it be required to ascertain the weight of B in proportion to A, so that they, being adjusted to equipoise, may continue to be in equilibrio, when left free to slide along K B. Since M R is the pressure produced by P Q, in a direction perpendicular to A G, we must add to this, H a, which is derived from the wedge A; therefore, make M n equal to H a, produce M R to Y, take Y Z equal to R n, draw Z W at right angles to K B; Y W is the force tending to make B slide up B K: take therefore B H′ equal to Y W, draw the perpendicular H′ b meeting the vertical B b in b; B b will represent the necessary weight of the wedge B; and the whole is so evident from the composition of pressures, as to require no farther demonstration." Such is Atwood's construction; he has rendered the demonstration much more prolix, by the unnecessary introduction of trigonometry; and after showing how the weight of the sections C, D, &c., may be found in the same way, he goes on to reduce these weights and pressures to analytical and numerical values. He finds

these in terms of the sines and tangents of the successive angles of inclination; but in reducing these to numbers, he has been led, by the accumulation of small errors, in that very operose way of proceeding, to give erroneous results; and into the singular mistake of conceiving, that the real expression of these values was only an approximation.

"The weight of the section C may be determined in the same way as the foregoing. But surely more simply thus: From C draw C S parallel to W Z, that is, at right angles to K O, and make it equal to W Z + H′ *b*; draw S *c* at right angles to L O, meeting the vertical C *c* in *c*, then C *c* represents the weight of C. From D draw D T parallel and equal to S *c*, draw T *d* perpendicular to D O, meeting the vertical D *d* in *d*, D *d* is the weight of D, and so on successively.

"Nay, instead of drawing D T parallel to S *c*, and T *d* perpendicular to D O, we may at once draw from S, S *d*′ perpendicular to D O, which will cut off for us *c d*′ = D *d*, the weight of the section D. It is of no consequence, although the lines of abutment do not all run to the same centre O.

"And thus we obtain a general construction for all the sections, which turns out abundantly simple; for upon any vertical line, *b*′ *e*, *Figure* 9, if *c b* be taken to represent the given weight of any section, C, and *c* T be drawn at right angles to C O, and *b* T at right angles to B O, meeting the other in T; then T *b* represents the pressure against the abutment O B, and T C the pressure against O *c*; and by drawing T *d* at right angles to D O, T *e* to E O, &c., we have the weights of the successive sections represented by *c d*, *d e*, &c., and the pressure on their lower abutments represented by T *d*, T *e*, &c.

"We may carry the same mode of determination to the other side of C, and pass the vertex of the arch. The divisions representing the weights of the sections will run upwards along the indefinite line *c b*′. The pressures on the abutments will be determined as before. Should the two sides of a section be parallel, the perpendiculars through T upon them will coincide; such a section, therefore, should have no weight. But should the two lines of abutment diverge towards the lower side, the line expressing the weight of that section will return upon the vertical, showing that such a section requires the reverse of weight, viz., a support from below. The line T V drawn horizontally through T, exhibits the horizontal pressure, which is uniform through the same equilibrated arch. But it is evidently greater, the less *b* T and *c* T are inclined to each other, the weight *b c* being constant, that is, the smaller the angle of the wedges, or sections. It also increases directly as the weight of the section C, &c. The line V *e* expresses the weight of the semi-arch, or perpendicular pressure on each pier; being the sum of the weights of all the sections in the semi-arch.

"Again, it is obvious that the angles *b* T *c*, or *c* T *d*, &c., are equal to the angles of the sections B O C, C O D, &c. If, therefore, the weight of any section, E, be given = *d e*, and the requisite angle of that section be required, everything else being known, we have only to join T *e*, and the line E *o*, being drawn perpendicular to T *e*, will exhibit the inclination of the lower abutment of the section; *d* T *e* is the angle of that section. And here it matters not where the point E be, that is, how great the base of the section be, provided the weight is equal to *d e*. We also see, that while the angles remain the same, and the weights proportional, it is of no consequence what the curve passing through the lower edges of the sections, or through their upper edges, may be, they may even be straight lines. According to this principle, the architect is not confined to given forms of intrados or extrados; he may take whatever curve appears most beautiful or useful: and, what is more, by the proper adjustment of the joints, *he may cast the ultimate pressure in any direction which he thinks most conducive to the strength of the edifice.*

"We now proceed to show the application of this investigation to some practical cases; and the first we shall consider, is that known by the common, though awkward name of the *flat arch;* one with which every mason is perfectly familiar, though it be seldom noticed by writers one quilibration.

"*Figure* 10.—A B *b a* is a structure of this kind, adjusted to this equilibrium, and resting on the abutments A *a*, B *b*. Its construction is exceedingly simple; nothing more is necessary than to draw all the joints, *m* M, *l* L, &c., to one centre, C: and the reason is obvious; for D K, K L, &c., are the differences of the natural tangents of the inclinations of the abutments, the perpendicular, C D, being radius; and the same thing is true in the line *d a*, and in every other parallel section. The surface, therefore, A *m*, M *l*, that is, the bulks or weights of the stones, are in the same ratio, and it is that which is required by the above principles. Also, if we assume the line of its base to represent the weight of any stone in the arch, for example, K D for half the keystone; then the perpendicular C D is the horizontal *thrust*, *drift*, or *shoot* of the arch. By increasing D C, or diminishing it, that is, by drawing the joints to a lower, or a higher centre, we may alter this thrust at pleasure. What if we should take C up to D? Some curious ideas occur here, but being chiefly speculative, we shall not now pursue them. They serve to connect this case very neatly with the lintel and the Egyptian arch, (or that formed by flat courses of stones gradually overlapping each other, until the opening be covered,) in each of which the horizontal thrust vanishes. We ought also to observe, that whatever weight of stuff lies on an arch of this kind, there is no change of design requisite, so long as the upper surface, or roadway, is horizontal. For being everywhere of the same height, the mass incumbent on any stone will be proportional to its base, viz., the back of that stone; since we must conceive the stuff to press vertically. It is therefore the same as if the whole arch had undergone a change of specific gravity; every pressure will be increased in the same proportion.

"The design of an equilibrated horizontal arch, or platband, being thus easily formed, it will not be difficult to extend it to a curve of any form; *a δ b b*′ *d*′ *a*,′ *Figure* 10, is an arch of this kind. It is a circular segment from the centre, C, to which the joints of the horizontal arch were directed; the two key-stones have the same weight and obliquity of abutment; consequently, the horizontal thrusts are the same. The other arch-stones being previously intended to have the same weight with those of the flat-arch, it is only necessary to draw the lines 1 1, 2 2, 3 3, parallel to M *m*, L *l*, K *k*, so as to produce this equality.

"This being merely a simple problem in mensuration, we shall not occupy the reader's attention with the solution of it. In the *Figure* referred to, we have divided the soffit, A B, of the flat arch into equal parts; all the stones, therefore, of that, as well as the curvilinear form, are of equal magnitude and weight, the angles of the arch-stones only, varying.

"The reader must have already observed, that when C D expresses the horizontal thrust, or pressure of the vertex, C M, C K, C L, &c. express the perpendicular pressures on the successive joints M *m*, K *k*, L *l*, &c. Now it is obvious, that K *k*, L *l*, &c. are proportional to C K, C L, &c.; for A D, *a d*, are parallel. Therefore, the vertical sides of the arch being parallel, the pressure on each joint of the flat-arch is always proportional to the surface of that joint, and the pressure on each square inch of joint throughout the arch is

always the same. It may readily be found too, by dividing the horizontal thrust by the area of vertical section, D *d*. This is a most valuable property, for it secures uniformity of action in every part of the structure. But it is not to be found in the arch *a b d*; for there, the joints being nearly equal, the pressure on each increases as we descend from the vertex, and may, at the lower sections, be eventually so great as to overcome the cohesion of the materials.

"It may be objected to the straight arch, that acute angles, as A *a m*, B M *m*, are very apt to chip away, and weaken the arch. Now this is certainly true, but it has no connection with the doctrine of equilibration. There is, however, a very ingenious mode of remedying it; for if the upper and lower extremities of each joint be drawn to a centre, considerably below the former, or even if they be formed into vertical lines, as at N, *n*, it will materially strengthen the acute corners without injuring the equilibration. We may conclude, therefore, that a structure of this kind possesses every requisite that can be looked for in an equilibrated arch. But, before we take any further notice of it, we shall proceed somewhat farther with the applications of our theory.

"The segment *a δ b* was adjusted to equilibrium, with reference to the flat arch, upon the principle that the weight of the arch-stones was only to be provided for. In general, an arch of this kind is filled up at the flanks, so as to form a roadway as nearly as possible horizontal. We must, in that case, when considering the weight of each arch-stone, not lose sight of the difference of pressure upon it, arising from the varying height of the incumbent mass. Having, therefore, divided the back of the arch into sections, *d* 1, 1 2, 2 3, *Figure* 11, each containing one, two, or more arch-stones, and having drawn the vertical lines from these divisions to the line of roadway, we calculate the weight of the trapezoid of the stuff over each section; add this to the weight of the section; and divide the tangent line, or flat-arch, accordingly.

"We may even give a construction for this. The stuff over any section, 2 3, is proportional to the trapezoid, *t* 2 3 *v*, or nearly *t v* × *s w*; for we need take no notice of the small segment of the circle between 2 and 3, but consider the arch as polygonal, in which case the mean height is *s w*.

"But 1 2, 2 3 being equal, we have *t v* or 2 *y* as sine of 2 3 *y* (*i. e.*) as sine of the inclination of the arch; wherefore, drawing the mean height, *w s*, and producing C *w* to meet the perpendicular *s x*, take the weights over the sections to be represented on the horizontal line, by lines equal to *w x* respectively; for *s w* is to *w x* nearly as 2 3 is to 2 *y*, and *t v*, at the vertex of the arch, is equal to 2 3; and since the weight of the arch-stone will be nearly constant, and that on the supposition that the weight over each section is represented by the trapezoidal space included between it and the roadway, let us assume the weight of the keystone, as represented by the part *d* P, and the others by similar additions. If we have an arch differing in gravity from the stuff which loads it, we can measure to a circle within or without the circle of intrados, P T *u* W. Draw, therefore, the horizontal line P *o*, and lay off P *a* equal to $\frac{1}{2}$ P *q* for the half keystone and its load, lay off, also, *a b* = *l n*, *b c* = *u x*, &c., and these divisions will represent the weight of the several sections, the superincumbent matter being included.

"This method is evidently only an approximation; we consider the principal load as arising from the mass incumbent on each section, or at least that the weights of the sections are proportional to these masses. It becomes pretty accurate, by taking *w* in the mean circle drawn between the soffit and back of the arch; and we might render it still more accurate, by giving the determination a fluxionary form, but we write at present for the practical builder, to whom the calculus is seldom known; besides, as the reader will see hereafter, we do not think the rigid determination of this matter as yet of much consequence.

"Having thus discovered the weights of the sections, and laid them off on the horizontal line, as if for a flat arch, and having, either from the given form of the keystone, or the horizontal thrust, drawn the angles of abutment which a flat arch would require, the joints of the arch in question are to be drawn parallel to these, and through the extremities of the proper sections, previously marked out, as above mentioned. If there be intermediate joints, they may either be drawn properly related to the others, or be separately discovered by a repetition of the construction.

"*Figure* 11.—For example, let C be the given centre for the keystone; draw C *a*, C *b*, C *c*, &c.; and through 1 draw the joint 1 R parallel to C *a*, also 2 T parallel to C *b*, and 3 W to C *c*, &c.: the arch would then be in equilibration.

"Thus we find, that, *by the proper adjustment of the joints to the weight of the section, we may form equilibrated arches, having soffits of any figure that may be thought proper*, and with any proportion of dead weight over them that circumstances may require. Let us now look at the converse of this Problem; where the inclinations of the joints being given, it is required to discover the mass or weight which must be allotted to each section, so as to preserve the whole in equilibrium.

"Pursuing the mode already employed, it is evident, that if we lay off from one centre the angles to be formed by the successive joints, or abutments, with the vertical line, a horizontal line drawn to cut them will represent, by its successive segments, the weights of the several sections; while, at the same time, the perpendicular let fall from the centre on this line will exhibit the horizontal thrust. If the arch, therefore, must be throughout of equal thickness, we have only to mark off upon the soffit, or rather upon the mean curve, segments proportional to those of the horizontal line. If the upper and lower outline of the arch be determined, we must divide it into trapezoids, having the same proportions; then draw the joints parallel to the lines expressing the given angles of inclination. Such joints will run to several different centres, thereby showing us, that their union in one is not at all necessary to the security of the arch, even should that be a portion of a circle.

"The position of the joints is usually given in a different way from that which we have just considered. In circular arches, they are generally formed by producing the radii from the centre; and in others they are commonly drawn perpendicular to the curve. Now, though we have just shown, that this is by no means necessary to the equilibrium, yet, as it is in reality the most convenient in practice, it may be of importance to attend to the effects likely to be produced by this modification.

"*Figure* 9.—We see that the tangents on the horizontal line rapidly increase as we pass outward, and we should therefore increase, in the same proportion, the weight of our sections. We cannot increase the base, as proposed above, for that is necessarily given by the position of the joints, but, as we are still able either to increase the height, or the breadth of the sections, we may consider the effect of both these modes.

"Let it be required, then, to equilibrate a circular arch, where the stones being all of equal thickness, with joints equally distant, are drawn all to one centre, we are only at liberty to increase the width of the roadway, or length of the horizontal courses.

"Considering each course of arch-stones as a prism of a given base, a supposition sufficiently accurate, it is evident,

that its magnitude or weight increases with the length only. But this weight must, from the principles already laid down, be as the difference of the tangents of its abutments; the length, therefore, must be in that ratio. Accordingly, we find the breadth at different distances from the vertex, in the same way with the weights of the sections: the breadth at 45° must be double, and at 55° must be about triple of that at the crown, and will increase still more rapidly afterwards. Proportions such as these may answer well in the short flight of steps for a flying staircase, but are quite unfit for our present purpose. When we recollect, however, that in a bridge, the extraordinary expansion towards the haunches is materially corrected by the increased pressure of the incumbent mass in that part, we are encouraged to proceed a little farther, and consider the effect of the second mode of effecting the equilibrium.

"*Figure* 11.—The pressure of matter upon each section has already been stated as proportional to $t\,v \times s\,w$; but $t\,v$ is the difference of the sines of the angular distances of the successive abutments from the vertex, and $s\,w$ is the mean versed sine added to the given thickness at the crown, when the roadway is horizontal. We have therefore the pressure as the difference of the sines × (mean versed sine + thickness at vertex.) But these pressures are also, from the theory, as the difference of the tangents of these angular distances.

"In the common mode of building we must give the arch a sufficient thickness at the keystone, to resist the horizontal thrust, ensure stability, and bear the loads likely to come upon it. We must also cover this part with a certain thickness of gravel, or other matter, so as to form a roadway. The varying pressure of the wheels of a loaded carriage, when it is propagated through this stratum of gravel, will be so far diffused as not to disturb the stone immediately below it, nor injure the bridge by splintering away its corners. This thickness is made as small as possible, that the bridge may not be unnecessarily elevated, and the roadway is preserved nearly horizontal. The other courses of arch-stones, too, do not often differ much in thickness from that at the crown. But although these things are pretty constant, there is a considerable degree of latitude in filling up the space between the back of the arch and the roadway. It may be done with substances varying in density, from the lightest charcoal or pumice, open shiver, or chalk, to closely rammed clay, or even solid masonry; and it is not uncommon to make, in various ways, open spaces in the masonry of the spandrel, covering them above, so as still to support the roadway.

"It will, therefore, be proper for us to inquire, what is the density requisite over every section of an arch, where the thickness of the crown is given, the roadway horizontal, the arch of uniform thickness, and the angles of abutment of the several sections constant, that is, all drawn from the same centre; or, what is the same thing, let us suppose the structure built up to the horizontal roadway with parallel sides, and then inquire, what is the proportion between the pressure borne by each section in this way, and the pressure of equilibrium; we shall thereby discover the ratio in which the density of the backing must, if needful, be diminished; and the quantity of expansion necessary towards the springing of the arch, that the advantages of equilibration may be preserved, even in this state of things.

"Before we give a more rigid determination, we should wish to show the practical builder, that the solution of this problem may be easily approximated, by the help of the trigonometrical tables. For we may suppose the matter of the arch-stones to be the same in specific gravity with that which lies above it; and as there can be no impropriety in considering the arch as polygonal, from joint to joint, our mean versed sine is only half the sum of those at the two joints. The supposition is not strictly accurate, but it is sufficiently near: greater strictness would only serve to render the calculation more complicated without making it more useful.

"It was customary in the construction of bridges, to fill up the haunch with solid matter, such as gravel earth, or the like, until a roadway of a proper slope was procured. Where the arches were small, this might not be attended with any perceptibly bad effect, provided the arch-stones were of a good depth. But the necessity of lightening the haunches, has been forced upon the attention of builders, whenever large arches have been attempted.

"In all probability, the first inventors of this mode of building, besides employing it with the view of equilibrating the arch by lightening the part over the haunches, had also an idea of steadying it by the lateral abutment. They appear to have considered the spandrel walls as a sort of hoops, that would keep the parts of the arch together, and hinder any stone from moving, by their great friction, inertia, and mutual abutment. Hence various ingenious modes have been employed for locking them into the back of the arch-stones, propagating the pressure through, and securing them from sliding away at the bases.

"They indeed act in this way; nevertheless the equilibration of the arch should be attended to in their construction, that every unnecessary strain may be avoided. The thickness of these walls may be varied indefinitely, and the vacant spaces made in any proportion to the solid parts. The walls ought to be near each other, that their effect may be felt over the whole arch, and perhaps they should spread out towards the bottom; but this is not so very necessary, for the courses of arch-stones break joint with each other, and the inequality of pressure in one course is immediately corrected by being propagated to the succeeding.

"We have now determined a method of constructing an equilibrated arch for sixty degrees on each side of the vertex; and this method, so far from having anything unusual, is even strictly analogous to that which is adopted by the practical builder. Why then cannot we keep pace with him throughout, and give a construction for the entire semicircle? No difficulty is felt by the mason in that case. He constructs such arches every day. Nay, they are not only the most common, but the most ancient of all arches. But the reader must have ere now observed, that our theory is in this particular defective. The enormous expansion of the roadway, or the infinite height of superincumbent matter, which it seems to require when the joints are nearly horizontal, are altogether preposterous and impracticable. We are sure they are unnecessary; for many semicircular arches have existed from the time of the Romans, and are still in good order. What is more, the failure of such arches near the springing, where they differ farthest from the theory, is a most unusual, and, indeed, unheard of phenomenon. Is our theory erroneous, then, or is it only defective? There is no reason for distrusting any of the consequences we have hitherto deduced. They are mathematically derived from an unquestionable principle, the action of gravity. But we have not yet considered all the causes of stability. The lateral resistance of the masonry, or other matter behind the arch, acts powerfully in preventing any motion among its parts; and independently of that, the friction of the arch-stones, assisted by the cohesion of the cement, affords a great security to the structure. We have even seen a semicircular ring of stones, abandoned to itself without any backing, and stand very well; long enough, at least, to admit of the other work being leisurely applied to it. Here was no lateral pressure; no equilibration: why did not the lower courses yield to the pressure

propagated from above, and slide off? It was only their friction that could retain them. It is greatly increased by this very pressure. And it is unquestionable, that a ring of polished blocks in that situation would not have hung together for a moment. The force of friction, therefore, makes so important a part of our subject, that it deserves a separate inquiry. Let us see how it may be estimated.

"When a mass of matter is moved along other matter of the same kind, the resistance produced by friction has been usually stated at $\frac{1}{3}$ of the weight. That of freestone, indeed, is supposed to be greater than $\frac{1}{3}$, perhaps it is $\frac{1}{2}$. And in the case to which we are going now to apply it, there can be little doubt, that, aided by the inertia of the stones, and the cohesion of the cement, the friction is even much more. But this force is inert; and we are at present inquiring, how far we are benefitted by it in promoting the stability of our structure. It will, therefore, be proper to underrate it, at least until we discover how far we are warranted to say it must be beneficial.

"*Figure* 12.—Let L, M, N, exhibit the three sections (10° each) of an arch, which we may conceive equilibrated above the section L, or 60° from the crown. Draw L T, expressing the direction and magnitude of the ultimate pressure, perpendicular to the upper surface of L. In like manner, T V is the horizontal thrust, and V L the weight of matter over L to the vertex. Draw the perpendicular T *y b*; T L is the direction of the ultimate pressure when propagated to the lower surface of L; *y* L is its tendency to make L slide upwards along the joint. Now it is evident, that, if *y* L has to *y* T a less ratio than the friction has to the pressure, L will not move. Nay, what is more, L will itself have some weight. Take L *a* to represent it, which, in the case of equal sections, = the tangent *x z*. Draw T *a* for the ultimate pressure in the lower surface of L, and *a b* for the force to be resisted by friction, in this case equal to .1343, or about $\frac{2}{15}$ of the pressure, and of course less than the friction, which will at least be one-third of the same.

"Since L does not move upon the section M, they are to be considered as one solid mass, and we pursue the pressure through the section M. For this purpose, lay off *a c* for the weight of M, draw the perpendicular T *d*, and the parallel *c d* to the joint M O, *c d* is the force opposed to friction in that joint, and still is less than one-third of T *d*, the pressure being, in the case of equal sections, = .2796, or about $\frac{11}{40}$. Lastly, lay off *c e* for the weight of the lowest section, N, and draw as before. It is evident, that *e f*, the force opposed by friction here, is just equal to T V, the horizontal thrust, as might have been concluded without any investigation. In the case of equal sections, its proportion to T *f* or V *e*, the weight of the semi-arch or perpendicular pressure, is as .4425, or about $\frac{7}{16}$, which is probably more than the friction will oppose without other assistance.

"If, therefore, the friction on the horizontal bed at the springing be not equal to the thrust of the arch, we must increase it, as by dowelling it, for example, into the lower stones, or by backing it with other masonry, or by increasing the pressure on that joint, without altering the thrust of the arch, which may be done by thickening, or loading the arch just over the springing. And here the theorems for the extrados of equilibration come to our aid; for we see, that any quantity of matter may be laid over the springing-courses, and, far from disturbing the arch, it will tend to increase its stability.

"It may not be improper to inquire, what are the conditions for equilibrating an arch by means of the friction of its segments alone? that is to say, what are the alterations practicable in the position of the joints, or in the weights over the several sections, until the tendency of each section to slide is just balanced by the friction at its lower surface?

"Whether we inquire into the position of the joints, or the weight that may be applied, there are two cases; for the friction being an inert force, will resist the stone in sliding either upwards or downwards.

"1. Let it be required to determine the position of the joints in an arch, when each section is just prevented from sliding outwards by the friction at its lower surface.

"*Figure* 13.—Let the arch spring from a horizontal joint, as N *n*, where, of course, the friction acting in V N, is just equal to the horizontal thrust, and must therefore have to T *n'* or V N the weight of the semi-arch, the ratio which friction has to the incumbent pressure, say $\frac{1}{3}$. T N is the direction of the absolute pressure at the abutment N *n*. Take M M the weight of the section N, T M is the pressure on the joint of M, and making M T *m* similar to N T *n'*, M *m* will also represent the extreme friction in that joint, and T *m* its load, and so on successively. Wherefore, if T *m*, T *l*, &c. be found, the joints of the arch may be drawn at right angles to these lines respectively, and every stone will be exactly in the predicament of N, that is, just kept by its friction from sliding away.

"The positions of T *m*, T *l* may be readily discovered; for the angle *n'* T *m* must be equal to N T M. If, therefore, we make T *a* equal to T N, draw the tangent *a w*, and making *a b* = N M, and joining T *b*, we have *a* T *b* = N T M. And, in this manner, taking *a b*, *b c*, &c. for the weights of the successive sections from the scale, and drawing lines from T, the joints may be formed perpendicular to the lines thus drawn.

"*Figure* 14.—But a more convenient construction perhaps would be, to take the horizontal thrust, or quantity of friction in the vertical line c *d*, lay off the weight of the semi-arch *d a*, draw c *a*, make c *x* equal to it, also *x z*, mark off the weight of the sections along *x z*, and through the divisions draw lines from the centre; the joints required are parallel to these lines.

"II. Let it be required, in the next place, to determine the other limit to the position of the joints, or that in which each section is just prevented from sliding in, by the friction on its lower bed.

"Here it is evident, that as the friction acts precisely opposite to its direction in the former case, the joints may have on the opposite side, exactly the same degree of obliquity to the position of equilibrium. Draw, therefore, the tangent *v y* parallel to *a* c, cut it with c *v* equal to *a* c, lay off the weights of the sections along *v y*, and draw lines from c; these lines will exhibit the positions of the joints, which of course may be drawn parallel to them. We have marked these two limits of position in three joints of the half-arch above the same figure, assuming the friction at one-third, and taking the first section of 30° as equal to the thrust; and any other arch might have been introduced as well as the circular. Any of the lines in the triangle c *d a*, makes with the corresponding line in c *y v*, or in c *z x*, an angle equal to *a* c *x*, that is, when the friction is one-third of the pressure, equal to 18° 26′; and when the friction is one-half, this angle is 26° 34′. The position of any joint, therefore, may vary, in the former 18° 26′, and in the latter case 26° 34′, on either side of the position of equilibrium, before any sliding can take place among the sections. Nay, the friction of polished freestone is even more than one-half, perhaps it is two-thirds, of the pressure, which would give 33° 4′. And it is proper to observe, that this is not confined to the annulus of arch-stones, but holds equally with whatever weight the sections may be loaded. We may observe, then, that, in any arch, the position

of the joints may be varied about 20°, perhaps 30°, from that of equilibrium, before any derangement can arise from the sliding of the arch-stones.

"This is a most important conclusion, and leads to extensive practical consequences. It affords a true explanation of the facility with which arches are everywhere constructed, even by the common country mason.

"For this reason, therefore, we approve highly of the practice, which we believe is very general among artificers, we mean that of backing up the arch with solid masonry, for several courses above the springing. If great security is thought necessary, cement, being a compressible substance, ought to be sparingly employed in the vertical joints at the back of the arch-stones.

"The friction of the sections of the arch, as it permits a considerable variation to take place in the position of the joints, will also admit of a considerable deviation from the load which is necessary for equilibrium over any point of the curve.

"It would not be difficult to investigate the extent to which this variation of weight might be carried. But we shall at present only remind the reader, that, as we find a variation of 20° practicable in the position of the joints, he may conclude that each section will admit of its load being altered to that which would suit a point in the curve 20° on either side of it.

"One thing only remains to be considered in this department of our subject, which is, the lateral pressure likely to arise on the back of the arch, from the materials employed to raise the structure to the horizontal line.

"If the materials employed here be only a solid mass of masonry, it is not easy to see, everything being steady, how it can act in any other way than in the vertical direction. If, however, a motion takes place in the arch, the mass of materials lying nearly over the springing, when the arch is not very different from a semicircle, will have such an enormous friction, if well built and bonded together, as would appear equal to the resistance of any pressure that is likely to be opposed to it. And when the arch is a segment much smaller than a semicircle, the rules we have already given for its equilibration must be considered. But, instead of solid courses of masonry, the haunches of arches are often filled up with coarse gravel, or shiver, and sometimes with mere earth or sand. Materials of this description do by no means act by mere dead weight. They have a tendency to slide down towards a horizontal position; and, of course, possess, in some slight degree, the *quaquaver sum* pressure of a fluid. This may act on our arch in a manner altogether new, and produce strains for which hitherto we have made no provision. We shall first consider the back of the arch as filled up with a fluid substance, as water. The pressure in every part will be in a direction perpendicular to the curve, and will be proportional to the depth. A pressure perpendicular to the curve will be equivalent, in effect, to a vertical pressure, which exceeds it in the ratio of the secant of the inclination to the vertical. Of course, the pressure at the springing, when all is equilibrated, must be equal to the horizontal thrust in a semicircular arch.

"Though the action of sand, gravel, or mould, in situations such as this, be not exactly the same with that of water, in following the laws of hydrostatical pressure; yet these materials resemble water, and may be conceived to hold the middle place between the fluid and the solid backing. In some respects they are more advantageous than the fluid. They are stiffer, so to speak, affording a lateral abutment to the arch, if it is likely to yield; and as the parts have a great friction among themselves, it will require a much greater pressure, acting horizontally, to make the matter rise, than in the case of a fluid. We must not, however, be too confident. Materials of this kind are compressible; and we have already seen that very slight shifts are attended with dangerous consequences. At the same time, we need not be much afraid of a trivial departure from exact equilibration; for it is not likely that materials of this kind will act with the powerful effort of hydrostatical pressure.

"But there is another case, where matter of this kind is likely to be attended with more pernicious effects than even a fluid of equal density would be. We mean, when the back of the arch is gorged up with water from land-floods: if the backing be open gravel, or shiver, we have superadded to its weight that of the whole quantity of water admitted into the structure. This, even if it acts equally on both sides, must be a dangerous experiment on any arch; but where it is confined to one side, as is generally the case, and between lofty side-walls, the effects are likely to be serious indeed. Accordingly, the builder forms gutters in the side-wall to let off the water ere it collect;—a practice which is in general highly useful, but which, in the case of sand, clay, or mould, is of small service. The water enters into such matter by its capillary attraction; and fills it to the upper surface, in spite of our gutters. It of course expands it, and this with a force which we cannot measure, but which we are sure is very great. Here the friction of the parts, which was so useful in the former instance, proves extremely hurtful. For as the matter cannot easily rise, and probably the adhesion of its particles is increased by the water, the expanding force becomes an enormous hydrostatical pressure acting perpendicularly on the side-walls and extrados of our arch, and which in all probability they may not sustain.

"The dangerous consequences of this mode of backing are, in some degree, prevented by ramming the layers of matter, especially if it consists of mould or the like: or, by puddling them, so as to form a mass impervious to water. And here we should observe, that as this ramming will produce an extraordinary lateral pressure, we must attend to equilibration, as we rise along the arch, and secure the side-walls by thickening them below or curving them horizontally or vertically.

"The thickness of the arch-stones is an important department of the theory of arches. It is natural that we should endeavour to make them as small as possible. That will diminish the expense of the structure, lessen the pressures in the arch, and increase the security at the springing. But there is an evident limit to this diminution; for though we take every pains to render the joints close, the stones may come at length to be so small as to crush by the thrust of the arch. This is, indeed, a curious branch of inquiry. It depends intimately upon the corpuscular actions of the particles of stone; a subject on which, we regret to say, our information has been hitherto very scanty.

"The question evidently depends on the amount of the tangential pressure. At the crown this is the horizontal thrust. We shall suppose all the joints to be duly drawn to equilibration, the sections fairly abutting on each other, and no weakness arising from acute angles.

"Stone, it is said, will carry from 250,000 to 850,000lb. avoirdupois per foot square, and brick 300,000lb. They have been made practically to carry one-sixth of this, and even more. The pillar in the centre of the Chapter-house at Elgin carries upwards of 40,000lb. on the square foot, and there was formerly a heavy lead roof on it. It is a red sandstone, and has borne this pressure for centuries.

"We shall therefore take 50,000lb. per foot as a load which may be safely laid on every square foot in the arch.

A cubic foot of stone weighs about 160lb. per foot; and brick weighs less. Suppose, therefore, the arch to be one foot thick at the crown, and the keystone one cubic foot, it will bear a horizontal thrust of 50,000lb. that is, 312½ times its weight.

"But, 50,000 : 160 : : R : Tang. 11′ 0″ 3‴, which will be the angle of the keystone in that case. So that an arch of 312½ feet radius, or a semicircular arch of 625 feet span, might bear to have a keystone of a foot deep, without risking its being crushed more than in structures which have already stood for many years. And this may be called the limit of stone-arch building; for if we double the depth of the stone, we will thereby double the weight also, and its ratio to the horizontal thrust will still be the same. Indeed this limit does not much exceed what has been actually executed. A considerable portion of the bridge of Neuilly is an arch of 250 feet radius; and Gautier mentions a platband in the church of the Jesuits at Nismes, the camber of which, after settling, would make it a portion of an arch of 280 feet radius. The length or span is 26½ French feet, the rise only 4 inches, and therefore the diameter of its circle would be 560 English feet.

"'This singularly bold platband was made under the conduct of Père Mourgues, after the design of Cubisol, an able architect. The stones are 1 foot thick, their depth is 2 feet towards the key, and 2 feet 4 inches at each end. It had a camber given it of about 6 or 7 inches, and descended near 3 inches on striking the centres.'"—*Gautier*.

"We see, that the horizontal pressure does not determine the vertical thickness of the arch-stone. But as we pass down the arch, it is plain that the butting surfaces must increase in proportion to the increasing tangential pressure.

"At sixty degrees from the vertex, granting that the arch is equilibrated, the depth of the arch-stones must be doubled; and, though the equilibration be carried no farther, yet, at the springing or horizontal joint, a small increase will still be necessary. The ratio will soon be found. To the square of the weight of the semi-arch, add the square of the horizontal thrust, the square root of the sum is the pressure at the springing. If we divide this by the horizontal thrust, it will give the thickness at the springing, compared with that which is necessary at the crown. Or if we divide it by 312½, it will give the smallest depth of joint which should be used at the springing. The thrust and weight are supposed to be given in solid feet. If given in pounds, divide the above quotient by 160, or divide at once by 50,000.

"If we calculate upon the same principles, the depth of arch-stone at the spring-course of a semicircle of 100 feet span, 10 feet thick at the crown, we shall find it to be 5 feet, and at the crown the depth may be 19 inches. In the great arches of the bridge of Neuilly, the thickness at the crown is about 4 feet 8 inches, the span 128.2 feet, and height 32. The horizontal thrust is great, the crown being drawn with a radius of 150 feet; consequently, this arch would require a depth at springing of about 4 feet. But when the centre was struck, the crown of this arch descended 23 inches, which has rendered it a portion of a much larger circle, and has greatly increased the horizontal thrust.

"The piers and abutments of a bridge must be so constructed, that each arch may stand independent of its neighbours. For though, by the mutual abutment of arch against arch, the whole may rest upon very slender piers, if once the structure is erected; yet, as they must be formed singly, and are exposed to many accidents, it will be best to contrive them, so that the destruction of one arch may not involve in it that of the whole.

"Some of the writers on the principles of bridges, in treating this department of their subject have found it necessary, by the help of the higher calculus, to find the centre of gravity of the semi-arch. The solution of the problem, we are convinced, so far as it is useful in practice, lies much nearer the surface.

"The reader has already frequently seen, that the ultimate pressure may, in every case, be reduced to two others, viz., the weight of the semi-arch above, and the horizontal thrust. In the equilibrated arch, this pressure is directed perpendicularly to the joints of the sections; and these being usually drawn at right angles to the curve, the pressure is in the direction of the tangent to the arch. Hence, we have often called it the tangential pressure. Upon this principle, however, when the curve springs at right angles to the horizon, an infinite pressure is required in the vertical direction,—a supposition which cannot have place in practice. We must accordingly call in the assistance of friction in that case; a force which may be set in opposition to the horizontal thrust, and which, increasing with the superincumbent weight, very fortunately keeps pace also with what it is intended to oppose.

"Granting, then, that the friction is so contrived, upon the principles already explained, that there is no danger of any slide at the horizontal or springing-joint; it will be readily admitted, that no slide is likely to take place in any horizontal course below that, till we arrive at the foundation; for the disturbing force is constant, but the friction increases as we descend.

"*Figure* 15.—Our principal care then must be, that the pier does not overset, by turning on the farther joint, E, o its base, as a fulcrum. Take *a* in the horizontal joint, A *a* as the centre of pressure; draw *a* v to represent the weight of the semi-arch, and v T the horizontal thrust; then T *a* is the ultimate pressure; and if, when produced, it falls within the base of the pier, it is perfectly obvious that it can never overturn it. And this is altogether independent of the weight of the pier: for if that were a mass of ice, immersed to the springing in water, the case would be exactly the same.

"But the pier itself has a considerable stability, arising from its own weight; and even though the direction of the ultimate pressure of the arch alone pass out of the base, the tendency to overturn the pier may be balanced by its weight. This weight may be supposed concentrated in the centre of gravity of the pier, and of course to act in the vertical line which bisects it.

"Its effect will be nearly found by laying off in that line from the point *q*, where the direction of the ultimate pressure of the arch intersects it, *q r* = the weight of the pier, and taking *q s* = the ultimate pressure = *a* T, and completing the parallelogram, the diagonal drawn from *q* will represent the direction and magnitude of the united pressure of the arch and pier. This is not strictly accurate; it would be so if *a* and *q* coincided, which is the case with a single arch standing on a pillar: but in general, the ultimate pressure is still more favourable than this. Its direction at any point is in the tangent of a curve, which approaches the vertical as we descend, since the proportion arising from the weight of the pier increases with its height.

"In order to find analytical expressions for these forces, let the horizontal thrust of the arch = *t*. The weight of the half-arch = *a*, and that of the pier = *p*, the height of the pier to the springing of the arch = *h*, the breadth at the base = *b*.

"1. Then the horizontal thrust acting in A G, tends to overturn the pier, and its force round the fulcrum, E, will be represented by multiplying it by the perpendicular distance A D, viz., $h \times t$.

"2. The weight of the pier acts in the direction B C, and its effect will be represented by multiplying it by the leverage C E, viz., $p \times \frac{1}{2} b$.

"3. The arch acts with the leverage E K, which is not equal to the breadth of the pier, by the part K D = A H, say one-half of the depth of the joint at the springing. This will never exceed one-fourth of the breadth, when two different rings of arch-stones rise from the same pier, unless the pier widen below. Call E K, therefore, $= \frac{3}{4} b$.

"We have now $h\ t = \frac{1}{2} b\ p + \frac{3}{4} b\ a$; whence,

"1st, $b = \frac{h\ t}{\frac{1}{2} p + \frac{3}{4} a} = \frac{4\ h\ t}{2\ p + 3\ a}$, and consequently,

to find the least breadth of the pier at its base, divide the horizontal thrust by half the pier added to three-fourths of the half-arch. Multiply the height of the pier by the quotient.

"2d, $h = \frac{b\ (\frac{1}{2} p + \frac{3}{4} a)}{t}$, that is,

the height of a pier to the springing, having a given base and weight, is found by adding the half-pier to three-fourths of the arch, multiplying by the breadth of the base, and dividing by the horizontal thrust.

"3d, $p = \frac{h\ t - \frac{3}{4} b\ a}{\frac{1}{2} b} = \frac{2\ h\ t}{b} - 1\ \frac{1}{2}\ a$;

or the weight of the pier cannot be less than the excess of the horizontal thrust multiplied by twice the height of the pier, and divided by the base, above one and a half times the semi-arch.

"In the above determination it may be observed, that we consider the weight of the pier as independent of its base. Now, though it may be said with propriety, that the weight of the pier cannot be known until we know its thickness, which is the very thing sought, yet a little consideration will show, that we may give different magnitudes to piers which have equal bases, and that, either by altering the outline of their sides, the density of their structure, the gravity of their materials, or the weight of solid matter over them, we may therefore, when the base is given, apply the weight necessary to keep the pier in equilibrio, provided this does not require the pier to be any more than a solid mass up to the roadway. Should the base assumed admit of the pier being much less than the solid parallelopiped, we may diminish it in various ways: as, 1st, By opening arches over the pier, where, in case of floods, we will procure an addition to the water-way; a practice very usual in the ancient structures: or 2d, By tapering the pier towards the springing of the arches, or by making each pier only a row of pillars in the line of the stream, arching them together at top; a mode which may perhaps be objectionable in a water-way, but which would have a very striking and light effect in land-arches. Something of this kind has been done by Perronet, at the Pont St. Maxence.

"When piers indeed are to be exceedingly high, as in the columns which are sometimes employed in supporting a lofty aqueduct, the best way is to make them hollow, and give them stability, by enlarging the base. They will, in that case, press less on the foundations, be less expensive, and they may be greatly stiffened by hooping.

"Indeed, it is not usual to make piers solid all the way up to the road; the spandrel-walls are carried back so far as to unite with those of the neighbouring arch, are locked together by a cross wall just over the middle of the pier, having also walls longitudinally, and the whole arched or flagged over from spandrel to spandrel just under the roadway.

"Nevertheless, as the case of solidity will enable us to assign a limit to the breadth of piers, which it may be proper to be acquainted with, we shall proceed in that investigation.

"The weight of the pier in that case will be as the rectangle under its height and thickness, expressing the weight of arch and pier by the cubic feet of stone. The pier indeed will be somewhat more; for the sterlings, or breakwaters, at each end, will add something to its stability; and this will be still farther increased in proportion to the horizontal push, if the whole bridge be wider at the foundation than at top, as is very common. Excluding these collateral advantages, we shall consider the whole as rectangular, and then the stability may be found in the longitudinal section. We have already $b = \frac{h\ t}{\frac{1}{2} p + \frac{3}{4} a}$, and in the case of a parallelogram $\frac{1}{2} p = \frac{1}{2} b\ (h + c)$, c being the height from springing to the roadway. By substitution, there arises $\frac{1}{2} b^2\ (h + c) + \frac{3}{4} a\ b = h\ t$; and by resolving this quadratic equation, we have $b = \sqrt{\frac{2\ h\ t}{h + c} + \left(\frac{3\ a}{4\ (h + c)}\right)} - \frac{3\ a}{4\ (h + c)}$

or thus, $b = \frac{\sqrt{2\ (h + c)\ h\ t + \frac{3}{4} a\ |^2} - \frac{3}{4} a}{h + c}$, as a formula for the thickness of solid piers to support equilibrated arches; and it must be observed, that if the arch be understood to act otherwise than at three-fourths the thickness of the pier, this co-efficient may be altered accordingly.

"When the arch is a segment less than a semicircle, a greater thickness of pier becomes necessary. For, the span continuing the same, we must either make the arch a part of a circle of greater radius, which would increase the horizontal thrust, or we must, in order to obviate that, diminish the thickness at the crown. In either case the weight of the arch is diminished, and with it the assistance which it gives to the stability of the pier.

"There is an interesting subject of inquiry, which might not be unappropriately noticed here; we mean the lowest versed sine that can be used for arches in proportion to the span. We conceive this, however, as in a great measure a practical question. We have already given some idea of the greatest possible arch of stone, or brick; a segment of that circle may, of course, be employed in any situation, but the piers (if the arch be of considerable span and height to the springing) must be made very great. Indeed, the investigation depends intimately on the thickness of piers. We ought to know the dimensions of the largest pier that can be trusted, and this, we conceive, depends chiefly on the care of the mason; for stone, and especially cement, is a compressible substance; and when an arch is very flat, a very small yielding at the springing produces an enormous depression at the crown, insomuch that there may be reason to dread, lest the arch pass down below the horizontal line, and fall to pieces before the stability of the abutments can be acted upon. A compression in the joints is equivalent to a yielding at the abutments, and appears equally difficult of remedy.

"In great horizontal thrusts, where the segment is flat, the immersion of the pier in water comes to have an important effect. On the weight of the pier, in those cases, the stability chiefly depends, and a deduction from that of two-fifths must be compensated by enlarging the thickness.

"But, indeed, the immersion of the pier, if it be very tall, that is, if the depth of water be great in proportion to the span, will demand attention, although the arch should not be very flat. In such a case, the stability arising from the pier is often as great as that which is derived from the weight

of the arch. It can seldom be greater, and consequently can seldom require, an addition of more than one-fifth of that breadth, which would be sufficient were there no immersion.

"But although the total immersion, even of a lofty pier, will seldom require any great alteration in the thickness, there is yet another circumstance which well deserves attention. Bridges are often built, especially in a tideway, with the arches springing below the high waters; we have in that case a diminution from the weight of the arch itself; but unless the keystone be under water, the horizontal thrust is unchanged; we must, accordingly, in our calculation, make the same diminution for that part of the arch which is thus immersed, as we did in the above example for the piers. The result will oblige us still more to increase the thickness of pier.

"On the whole, we may conclude from this investigation respecting the piers, that the increase of breadth which may be, and usually is, given to the pier, is of much less importance, on account of the weight that is thereby gained, than by its increasing the length of that arm of the lever, whereby the weight of the whole resists the effect of the horizontal thrust oversetting it.

"Instead, therefore, of building up the pier with perpendicular sides, we should think it more advisable to begin the foundation of the pier on a base much wider than usual, and from thence, by regular recesses, or otherwise, gradually to diminish it, until, at the springing of the arch, it does not exceed the depth of the two arch-stones, while the outline of the pier may be a curve of any shape that is most pleasing. Many advantages would, in our opinion, be obtained by this construction: the water-way will be enlarged; the pier equally strong; the stability equally great, nay, much greater than usual; and the chance of the foundations being hurt in floods will be greatly diminished; and all this with a smaller quantity of materials."

It is manifest, that before an arch of equilibration can be destroyed, the pressure applied must be so great as to overcome the resistance offered by the friction of the adjoining voussoirs, or the adhesive power of the cements; and be it remembered, the greater the pressure, the greater also is the friction. We give the following as a method of discovering the extent of license allowed in practice, on account of this quality in the materials employed.

To find the quantity of friction in individual instances,—Place the stone to be used upon a platform of the same material, and raise up one end of the platform, until the least additional elevation would cause the stone to slide down, and measure the angle of elevation so found.

Now the effect of friction is this, that instead of being compelled to place the joints of the voussoirs in the position assigned them by theory, we may place them in any position on one side of it, provided the joints fall within an angle from their theoretical position, not greater than the angle of elevation, determined as above; or if the joints of the voussoirs are maintained in their original position, we may allow a proportionate variation in their weight. On this account very great latitude is allowed in construction, for we may depart very far from the rules laid down from theory, before we can endanger the stability of the edifice.

Dr. Robison is of opinion, that the voussoirs may be considered as a solid mass, and that the principal object to be attended to, is that the arch should be made so flat, as to admit the same straight line being drawn in such a manner as to pass through some point in every voussoir on either side of the keystone, and where this is impracticable, he recommends that the straight line should be carried through as many arch-stones as possible, and that the arch should be carefully loaded at the intersection of such lines, considering each number of voussoirs passed through by one line as a separate block of stone. Generally, he supposes, that the pressure at the crown, is communicated in a straight line through as many stones as one straight line will pass through. All suggestions, however, on this subject, must be attended with considerable doubt and difficulty, as we are almost entirely ignorant of the method by which the communication and distribution of pressure is regulated, and even, in many cases, of the nature of the materials employed.

In accordance with the intention expressed by us in our article on BRIDGES, we now proceed to give a description of the principal stone bridges erected over the Thames, commencing with Westminster, as being the oldest. The first stone for that bridge having been laid on January the 29th, 1739, by the Earl of Pembroke, and the bridge itself being entirely completed on the 10th of November, 1750.

WESTMINSTER BRIDGE was built according to the designs, and under the superintendence of, a Swiss architect, named Labeyle, who, in its construction, adopted the practice of forming the foundations by means of caissons, instead of driving piles into the ground, or making use of coffer-dams, according to the general custom. This he effected in the following manner:—Large timber cases, consisting of a strong platform, or raft, surrounded by sides, were made water-tight, and floated on the surface of the Thames to such places as the piers of the intended bridge were eventually to occupy. In these, when firmly moored in proper position, the masonry of the piers was commenced: the caissons gradually sinking in the water as the masonry advanced, until at length they finally settled on the bed of the river: the sides of the caissons were then removed, to be used elsewhere, and the piers, which were built of Portland stone in blocks, each of which was at least a ton in weight, and many of them weighing as much as five tons, were carried up to the springing of the arches. These blocks of stone were cemented together with Dutch tarras, besides being connected with each other by iron cramps fastened with lead.

The building of this bridge occupied nearly twelve years, owing to the plan that had been adopted in laying the foundation; in consequence of which, one of the piers sunk so much, as seriously to endanger the stability of the structure, and it was found necessary to put another in its place; this circumstance greatly enhanced the cost of construction, and the various sums expended amounted to £389,500. It appears that materials of this bridge, to the value of £40,000, are constantly under water. The caisson on which the first pier was erected, contained 150 loads of timber, on which were laid 3,000 cubic feet, or nearly three tons of solid stone.

Westminster Bridge is 1,220 feet long, and is 44 feet wide, including the foot-path for passengers on either side of the carriage-way; it consists of 13 large, and two small arches, 14 piers, and two abutments. The arches spring at about 2 feet above low-water mark, they are all semi-circular. The centre arch is 76 feet span, and the others decrease on either side by 4 feet, so that the arches near the banks of the river are only 52 feet span. There are, besides, the two small arches each of 25 feet span.

The piers are 70 feet in length, and terminate in cut-waters, pointing up and down the stream. Those which support the centre arch are each 17 feet wide, and every successive pier is diminished a foot in breadth, so as to leave a water-way in the clear of 870 feet.

There was formerly a handsome stone balustrade, which formed the parapet of the bridge on either side, and over every pier there was a bay or recess, covered in with a kind of half cupola; while over the central arch, a rectangular

space increased the width of the bridge by means of a projection towards the water.

The soffits of the different arches in this bridge, were carefully turned in Portland-stone. Over this, another arch was formed of Purbick-stone, well bonded with the preceding, and so arranged as to make the thickness of the double arch about the haunches four times that at the crown. The spandrels were constructed with barrel and intermediate arches, so as to maintain the edifice in equilibrio.

When Old London Bridge was taken down, and a more uninterrupted outfall was thus afforded to the stream, the bed of the Thames became considerably deepened, and the foundations of the different bridges which had been previously constructed, were thereby more or less affected. Westminster Bridge suffered particularly from that cause; for, owing to the very insecure substructure on which it was founded, its piers have been gradually giving way for years; and, in consequence of the inequality of yielding which has taken place, the entire bridge is now in a deplorably dilapidated condition. It has been deemed absolutely necessary to prop up several of the arches by centerings, to remove the weight over others, and in order to prevent a too manifest appearance of the unsightly breaks which have taken place in the roadway, the stone balustrade has been replaced by a temporary wooden fence or parapet.——To our thinking, the repairs which it has lately undergone, were effected in a most injudicious manner. In the first place, the system of propping up some of the arches, and allowing others to sink freely, was highly prejudicial to the stability of the bridge; and indeed one of the arches was only partially supported, so that the remaining portion separated from it, and sunk several inches, to the imminent peril both of its real and apparent efficiency. Again, the uselessness of facing the piers with new stone, at a time when the entire demolition of the structure became inevitable, must be evident to every one who will give the subject but a passing consideration.

As, however, this bridge is to be taken down very shortly, and a handsome modern structure will ere long supply its place, we do not think it necessary to say more on this subject at the present time.

Next in point of date among the stone bridges of the Thames, is that of Blackfriars, which was commenced in the year 1760, and finished in 1770, by Robert Mylne, a Scotch engineer, who had just before returned from Rome, where he had been pursuing his studies, and where he had earned a well-deserved reputation; having received a silver medal from the Roman Academy, which he deposited, together with several coins of George the Second, in the foundations of the bridge.

Blackfriars Bridge is about 1,000 feet in length, and about 43 feet wide, including a carriage-way of 28 feet, and two raised footpaths for pedestrians, each 7 feet in width; it is built of nine nearly semi-elliptical arches, of which the centre one is 100 feet, and the others decrease in span, as they are placed nearer the banks of the river, being respectively 98, 93, 83, and 70 feet, by which it will be seen that there is a water-way of 788 feet in the clear. The roadway is a uniform curve, being the segment of a very large circle.

The architecture of this bridge is exceedingly beautiful, and great taste is displayed in the design; the bays over each of the piers being supported by Ionic columns, which give a light and graceful character to this really handsome edifice; and it is to be regretted, that the materials of which it is composed are of so perishable a nature. In consequence of the curved roadway, the entablature of the columns is not made horizontal; and the consequent inequality in the height of the columns, is a marked defect in an æsthetic point of view. The parapets of this bridge are formed by a very handsome stone balustrade, 4 feet 10 inches in height; so that, while the security of persons passing over the bridge is amply assured, the view both up and down the river is uninterrupted. The expense of constructing Blackfriars Bridge amounted to £152,840.

The plan of forming the foundations by means of caissons, was unfortunately again resorted to in this case, and although short piles were driven into the bed of the river on which the bottoms of the caissons were made to rest, still the scouring process to which the channel of the Thames has been subjected of late years, nas seriously affected the stability of the piers, and the change which has consequently taken place in the form of some of the arches, plainly point out the necessity of constructing a new bridge for this reach of the river at no very distant period.

Waterloo Bridge is one of the finest stone bridges constructed over the Thames; its bold, solid style of architecture being admirably suited to the character of a bridge over a large and important river, where massiveness and strength, combined with taste in design, have been judiciously and pleasingly combined; and when to these considerations are added the circumstance of its having a roadway perfectly level throughout, we may safely come to the conclusion, that it is one of the most successful specimens of bridge-building which has ever been produced. The celebrated Canova was loud in its praises, and extolled it as the *beau-ideal* of such constructions.

It was built by the late eminent engineer Rennie, who submitted two plans, one with seven arches, and the other nine; the latter was adopted, and the first stone of the new structure was laid in the October of 1811. The foundations he formed by means of coffer-dams, composed of three rows of piles one within the other, at a distance of about 3½ feet between the rows; the intermediate spaces having been carefully filled in with well-rammed clay. The water was then pumped out of the coffer-dam, and piles a foot square, and about 20 feet long, were driven into the bed of the river. A framework of timber was then constructed on the top of those piles, and the spaces between the pile-heads, to a depth of about a foot and a half, were filled in with stones tightly packed, and well grouted with liquid mortar. A floor of beech-planking, six inches in thickness, was bolted to the timber frame-work, on which the masonry of the piers and abutments was then commenced.

The entire surface-work of this bridge was built of Cornish granite, and the interior consists principally of Craigleith sandstone, well bonded, and cemented by a grouting of mortar. The spandrels of the arches were left hollow, to avoid an undue loading of the haunches, with the exception of six transverse brick-walls, for the purpose of supporting the roadway.

All the arches of the bridge are the same—semi-elliptical in form, 120 feet in span, and having a rise or versine of 35 feet. This allows a clear waterway of 1,080 feet. The piers are 87 feet long, from the extremity of one cut-water to another; they are 30 feet in width at the foundations, and diminish to 20 feet at the springing of the arches. Over each pier there is a rectangular recess, which is supported by Doric pillars, these, together with an open stone balustrade, give a certain degree of lightness to the edifice, without interfering with its characteristic solidity.

The entire length of Waterloo Bridge, including its approaches, which are built on land-arches, at either side of the river, is 2,456 feet.

This bridge took only six years to construct; and it was

so carefully put together, every stone having been accurately put into its place, and so well driven home, that on removing the centres, the arches did not sink more than an inch and a half at the crown; which is truly wonderful, when their immense span is taken into consideration.

Waterloo Bridge was built by a Joint-Stock Company, empowered by act of Parliament to raise a million of money; to pay off which, and reimburse its proprietors, a small toll is levied from passengers; and now that the South Western Railway is completed as far as the Waterloo-station, the traffic over the bridge, and consequently the returns derived from the tolls, have been considerably augmented.

London Bridge was built somewhat to the west of the site formerly occupied by Old London Bridge, an antiquated stone structure, that was erected about the beginning of the 13th century, by Peter of Colechurch, who combined the professions of architect and priest: he died in the year 1205, and was buried in a crypt within the centre pier of the old bridge, over which there was a chapel dedicated to St. Thomas à Becket.

The contractors for the building of the new bridge, Messrs. Jolliffe and Bankes, under the superintendence of Mr. (now Sir John) Rennie, the engineer, drove the first pile of a coffer-dam for the south pier, on the 15th of March, 1824.

The general form of the dam was elliptical. Three rows of piles shod with iron, and many of them measuring between 80 and 90 feet, were driven into the ground, and after being bolted together by means of walings, the spaces between them were puddled with clay, &c.; wooden stays or props were also placed between the different rows of piles and the interior space of the dam, strongly truss-framed between longitudinal beams. This coffer-dam having been completed, the first stone of the new bridge was laid by the then Lord Mayor of London, in the presence of H. R. H. the Duke of York, on the 15th of June, 1825.

Piles of beech-wood were driven into the natural bed of the river, consisting of stiff blue clay, to the depth of about 20 feet; two rows of horizontal sleepers, about a foot square, were laid on the tops of those piles, and these again were covered by a planking of beech, 6 inches in thickness; and on this flooring the foundations of masonry were laid. The same system was adopted for all the piers and abutments.

The construction of centering for the arches was the next step in this great undertaking. Each centre was composed of ten frames, joined together on the principle of the diagonal truss—each frame rested at either end on a pile driven into the river. The ten frames were then boarded over with planks placed within 2 or 3 inches of each other. In consequence of a difference in size in the arches, it was necessary to have four sets of centres.

On these centres the arches were turned in the ordinary manner, and in the spandrels hance-walls were built, longitudinally, so as to oppose the thrust of the arches without overloading the haunches. On the top of those walls heavy blocks of stone were bedded, and on these were laid stone landings, upon which was placed a layer of tarras, and over that again, the puddling, on which the roadway was formed. The first arch was keyed in on the 4th of August, 1827, and the last on the 19th of November, 1828.

The approaches on either side of the bridge were carried on arches over some of the streets running along the banks of the river. The arch over Thames-street, in particular, is worthy of attention, being very flat, having been constructed over the roadway and both the footpaths of Thames-street, and the centering for it had to be so made as to leave an uninterrupted passage for vehicles and pedestrians; it was entirely supported by struts ranged along the junction, between the carriage-way and footpaths, and the abutments of the arch; on these the wedges were placed upon which the centering was made to rest.

The only alteration in the original plan of Mr. John Rennie, the engineer who designed the work, was the addition of 6 feet to the roadway, and an increased height of 2 feet in the abutment arches. The alteration in the width of the roadway was loudly insisted on by the public; and the government ordered that the additional cost it would necessitate, should be met by a public grant to the amount of £42,000. The additional height in the side arches was proposed by the present Sir John Rennie, on whom the execution of the work had devolved on the demise of his father. This great undertaking was entirely completed on the last day of July, 1831, after having been about seven years and a-half in the course of construction.

London Bridge is composed of five semi-elliptical arches, four piers, and two abutments. The centre arch is 152 feet span, having a rise of 29 feet 6 inches above high-water mark. The two arches next to this are each 140 feet in span, and rise 27 feet 6 inches. The two abutment arches are 130 feet in span, and rise 24 feet 6 inches. The two piers which support the centre arch are each 24 feet wide, and the others 22 feet in width.

The line of roadway, which is the segment of a great circle, the rise being only 1 in 132, is marked externally by a modillion cornice, over which there is a close parapet wall in place of the open balustrade which we have mentioned connected with the other three stone bridges.

The abutments are each 73 feet at the base. On either side of these are two straight flights of steps, 22 feet in width.

The entire length of the bridge, from the extremities of the abutments, is 928 feet; and the clear water-way is 690 feet. The carriage-way is 35 feet wide, and each of the footpaths 9 feet.

This admirable bridge was built of the best Aberdeen, Penryn, and Heytor granite; and the quantity of stone used in its construction amounted to 120,000 tons. In addition to this, many of the arches forming the approaches were built of brick. The cost of construction for the bridge itself was but little over half a million of money; but the expense of making new approaches, purchase of land for the same, and cutting through valuable and important premises, increased the expense considerably; and the various sums expended on the new bridge, and the different improvements it rendered necessary, came to nearly two millions sterling; to which amount the government, however, contributed to a considerable extent.

London Bridge was opened to the public on the 1st of August, 1831, by King William the Fourth, who proceeded in state by water, to be present at the inauguration ceremony, attended by the most distinguished personages connected with his court; and the king took the opportunity of complimenting the citizens of London on the "skill and talent" which they had displayed in "many magnificent improvements," and especially in the successful accomplishment of that splendid undertaking. The day's festivity was concluded by a princely banquet, which was served up on London Bridge; and that beautiful erection, admirable in design—simple in appearance—but substantially useful in its character, became thenceforward public property, and was freely thrown open, without toll or restriction, for the use and benefit of the entire nation.

Skew Bridges may fairly come under the head of Stone

Bridge; for though they are frequently built of brick and other materials, the vast majority of such constructions are either formed of stone, or stone and brick combined.

Oblique, or Skew bridges, have been introduced contemporaneously with railways; for few bridges of the kind were constructed anterior to that time. We hear, indeed, of one having been thrown over the river Mugone, at Florence, so early as the year 1550; but the true principles on which oblique bridges depended were not previously known or studied, as their application to general purposes was rarely, if ever, absolutely called for, until the plan of rapid locomotion, which the system of railways gave rise to, made their use constant, and in many cases indispensable.

In the construction of oblique bridges, the main object to be kept in view is to bring the thrust of the arch into such a position as will enable the abutments, or piers, properly to counteract it; and the most effective way of so doing, and at the same time the most simple, is found to be by making the direction of the courses at right angles to the face of the bridge.

There have been various methods suggested for building these bridges; but the one most commonly adopted, is to form the arch by regular spiral courses, all parallel to one another, and so arranged, that any section taken at right angles to the axis of the cylindrical segment which constitutes the arch, shall exhibit the coursing-joints tending in a radial direction to the centre of the cylinder at the point of section. All the voussoirs are rectangular in plan, both on the extrados and intrados, with the exception of those on the faces of the bridge, because a spiral line, touching the outer edge of both abutments, would form a curve of contrary flexure, falling partly within and partly without the line bounding the arch. In this case, the face-line will evidently not be parallel to the heading-joints of the voussoirs, which, therefore, will be of a constantly varying shape and size on the faces of the bridge. Again; it is important to remark, that in this particular system of construction, the joints of the voussoirs are not, properly speaking, straight lines on the elevation of the arch, but segments, whose chords should all tend to a common centre, which, in every case, must be more or less below the axis of the cylinder, according to the angle of the skew bridge.

One of the best works on the subject of skew bridges, was written by Buck, wherein formulæ are given, from which all the dimensions of skew arches of every kind may be arrived at with mathematical accuracy, and the principles of their construction are clearly and correctly explained. Nicholson published two admirable works on this important department of bridge-building—one in 1828, entitled, "A Practical Treatise on Masonry and Stone-cutting;" and the other in 1839, called, "A Treatise on the Oblique Arch." To him we are indebted for the first sound exposition of the principles on which such constructions are founded; and from the practical bearing of this, as of all his works, it was of the greatest use in presenting the subject to men's minds in a correct and intelligible point of view, and setting it forth in its proper light.

The method of forming oblique arches, as above explained and treated of by Buck and Nicholson, supposes the arch to be a segment of a circle on the square section. It is not, however, necessary that such should be the case; the form of the arch may be elliptical on the square section, in which case the elevation is a much flatter ellipse, according to the amount of skew; as it is clear that the minor semi-axis is constant, while the major semi-axis will increase with the skew; and this arch may be again modified by making the joints of the voussoirs perpendicular to the radius of curvature on the square section, instead of making them tend to the axis of the cylindrical segment

Many changes of this kind have been recommended and tried, with varying success, by Messrs. Hart, Adie, Roebuck, and several others.

Stone Columns, such columns as are constructed of stone; in which, the fewer the joints, the better the appearance. If columns are necessarily composed of more than one piece, from the difficulty of procuring stones of sufficient magnitude, they ought to consist of three, five, or some odd number; more especially if the joints be few in number, than when they are many.

In columns constructed of several pieces, a mould must be made for every joint; and in setting the pieces, a sheet of thin milled lead, well bedded in white-lead, ought to be inserted between the joints, so as to come within about three-quarters of an inch of the convex surface of the column.

In the act of building, the diminishing rule ought to be applied to every course as it is set; and when the whole column is completed to its height, it ought to be tried again, and all the inequalities in the height reduced to the regular curve; for it is hardly possible, even though constructed by the best workmen, that some irregularities should not occur: and, at the same time, the circularity, or roundness, of the column ought to be attended to.

The most accurate method of fluting columns is, to cut the flutes after the columns are built, and brought to the curve; but in performing this, great care ought to be taken to prevent the chipping of the stone at the joints; which is best avoided by working each adjoining stone, or piece, from the joint, at least so far as to be out of danger of splitting the part of the stone next to it.

Stone Stairs, those constructed of stone. When stone stairs are supported by a wall at both ends, nothing difficult can occur in the construction; in these the inner ends of the steps may either terminate in a solid newel, or be tailed into a wall surrounding an open newel. Where elegance is not required, and where the newel does not exceed two feet six inches, the ends of the steps may be conveniently supported by a solid pillar; but when the newel is thicker, a thin wall surrounding it would be cheaper.

In the stairs of a basement story, where there are geometrical stairs above, the steps next to the newel are generally supported upon a dwarf wall.

Stone geometrical stairs have the outer end fixed in the wall, and one of the edges of every step supported by the edge of the step below, and constructed with joggled joints, so that they cannot descend in the inclined direction of the plane, nor yet in a vertical direction; the sally of every joint forms an exterior obtuse angle on the lower part of the upper step, called *a back rebate*, and that on the upper part of the lower step, of course an interior one, and the joint formed of these sallies, is called *a joggle*, which may be level from the face of the risers, to about one inch within the joint. Thus is the plane of the tread of each step continued one inch within the surface of each riser, and the lower part of the joint is a narrow surface, perpendicular to the inclined direction, or soffit, of the stair at the end next to the newel.

In stairs constructed of most kinds of stone, the thickness of every step at the thinnest place of the end next to the newel, need not exceed two inches for steps of four feet in length, measuring from the interior angle of every step perpendicular to the rake. The thickness of steps at the interior angle should be proportioned to the length of the step: but allowing the thickness of the steps at each interior angle to be sufficient at two inches, the thickness of steps at the interior angles will be in inches half the length of the steps

n feet: thus, a step of five feet long would be two inches and a half at that place.

The stone platforms of geometrical stairs, viz., the landings, half-paces, and quarter-paces, are constructed of one, two, or several stones, as they can be procured. When the platform consists of two or more stones, the first platform stone is laid upon the last step that is set, and one end is tailed in and wedged into the wall; the next platform stone is joggled, or rebated, into one set, and the end also fixed into the wall, as that and the preceding steps are; and thus with every stone in succession, till the platform is completed. If there is occasion for another flight of steps, the last stone of the platform becomes a spring stone for the next step, and the joint is to be joggled, as well as those of the succeeding steps, in the same manner as in the first flight. Geometrical stairs, executed in stone, depend upon the following principle: that everybody must, at least, be supported by three points placed out of a straight line, and consequently, if two edges of one body in different directions be secured to another, the two bodies will be immovable in respect to each other. This last is the case in a geometrical stair: one end of a stair stone is always tailed into the wall, and one edge either rests on the ground itself, or on the edge of the preceding stair stone, whether it be a plat or step. The stones of a platform are generally of the same thickness as those forming the steps.

Stone Walls, such walls as are constructed of stone.

The modern methods of constructing stone walls, with a description of the materials employed, have already been given under the head Masonry; we shall, therefore, confine this article to the construction of walls used by the ancient Greeks and Romans.

Vitruvius has left us an account of the construction of the walls of the ancients as follows: "The sorts of walls are the *reticulated*, (*Figure* 1,) and the ancient, which is called *the uncertain*, (*Figure* 2.) Of these, the reticulated is the handsomest, but the joints are so ordered, that all the parts of the courses have an infirm position; whereas, in the uncertain, the materials rest firmly one upon the other, and are interwoven together; so that they are much stronger than the reticulated, though not so handsome. Both sorts are formed of very small pieces, that the walls, being saturated with mortar, may endure the longer; for the stones, being of a porous and spongy nature, absorb the moisture from the mortar; and when there is an abundance of mortar, the wall, having more humidity, will not so soon decay, but will, on that account, be rendered more durable; for as soon as the humidity is extracted from the mortar by the suction of the stones, then the lime and sand separating, the cement is dissolved, and, the mortar, no longer uniting the materials, the walls soon become ruinous. This may be observed in some tombs near the city, which are built with marble, or hewn stone, and the internal parts rammed with rubble stones; the mortar being by length of time drained of its humidity by the suction of the stones, and the union of the joints being dissolved, they separate and fall to ruin.

"To avoid this error, the middle space (*Figure* 2) must be strengthened with abutments of the red hewn-stone, or bricks, or common flints, built in walls two feet thick, and bound to the front with cramps of iron fixed with lead; for the work being thus built in a regular manner, and not laid in promiscuous heaps, will remain without defect; and being, by the orderly arrangement of the courses and joints, firmly united and bound together, it will not be liable to fractures, nor will the abutments suffer it to fall to decay. For this reason, the walls of the Greeks are not to be despised; for though they do not use smooth or polished materials, yet where they discontinue the square stones, they lay the flints, or common hard stones, that they use, in the same manner as bricks are generally laid, bonding the courses together with alternate joints, and thus making their works strong and durable.

"These walls they build in two manners; one is called *isodomum*, (*Figure* 3,) and the other *pseudisodomum*, (*Figure* 4.) Isodomum is when all the courses are of an equal thickness; and pseudisodomum when they are unequal. Both these sorts are firm; first, because the stones themselves are of a compact and solid nature, and do not absorb the moisture from the mortar, but preserve its humidity to a great age; and, secondly, being situated in regular and level courses, the mortar is prevented from falling, and, the whole thickness of the wall being united, it endures perpetually.

"Another sort is that which they call *emplecton*, (*Figure* 5 and 6,) which is also used by our villagers. The faces of the stones, in this kind, are smooth; the rest is left as it grows in the quarry, being secured with alternate joints and mortar; but our artificers, quickly raising a shell, which serves for the faces of the wall, fill the middle with rubble and mortar; the walls, therefore, consist of three coats, two being the faces, and one the rubble core in the middle, (*Figure* 5 and 6.) But the Greeks do not build in that manner; they not only build the facing courses regularly, but also use alternate joints throughout the whole thickness, not ramming the middle with rubble, but building it the same as the face, and of one united coat they construct the wall; besides this, they dispose single pieces, A, which they call *diatonos*, in the thickness of the wall, extending from one face to the other, which bind and exceedingly strengthen the walls. Those, therefore, who would build works of long duration, must attend to these rules, and make use of such methods of building; for the smooth polish, and beautiful appearance of the stones, will not prevent the wall from being ruined by age."

STOOTHINGS, a term used in the north of England, and perhaps in some parts of the south of Scotland, for battening to walls.

STORY-POSTS, upright timbers, disposed in a story of a building, for supporting the superincumbent part of the exterior wall, by means of a beam over them. They are chiefly used in sheds and workshops. Story-posts should have a solid wall below, or they should stand upon a strong wooden sill, or upon inverted arches, or upon large stones, with their ends let into sockets. When the distance between story-posts is considerable, they should have two braces on either side; and these should be resisted at the top by a straining-beam, and at the bottom by joggles cut in the posts themselves; the upper surface of the straining-beam should also coincide with the lower surface of the upper beam, or bressummer. In cases where the distance between the story-posts is still greater than above supposed, not only braces and straining-beams are to be employed, but every interval should be arched upon the top of the bressummer.

Story-Posts, or Prick-Posts, as they are called in old books on architecture, are used in wooden buildings, between the stories, to support the floors.

Story-Rod, a measure used in staircasing, in length equal to the height of the story; or from the upper surface of the boards of one floor to the under surface of those of the next; it is divided into as many equal parts as there are to be risers in the stair, for the more accurately carrying up the steps.

STOUP, a stone bason, frequently found in the porches and at the entrances of our old churches, and employed to contain holy water, with which the worshippers sprinkled themselves upon entering the church. This was a relic of a very ancient practice observed in the early church, and the holy-water stoup seems to have been a substitute for the foun

tain which existed in the atria of the early churches. The stoup, or *benatura*, in our old churches, is of small size, usually situated in an arched recess, and of similar form to the piscina, which, however, has its place by the side of an altar, and was used for a different purpose. Many examples still exist of various forms, and of different degrees of ornamentation.

STRAIGHT-JOINTED FLOOR, a floor in which the joints are continued from one end of the apartments to the other; and where the heading-joints are not in the same straight line, as in folded floors.

STRAINING-PIECE, or STRUTTING-PIECE, a piece of timber acting in opposition to two equal and opposite forces at its extremities, for the purpose of preventing their nearer approach towards each other. Principal rafters, camber-beams, hip-and-valley rafters, collar-beams, or straining-beams, auxiliary rafters, or principal braces, struts, studs, and story-posts, are all of this description. Straining-pieces are distinguished as beams or sills by the term *beam* or *sill* immediately following the word *straining;* as *straining-beams, straining-braces*, or *straining-sills.*

STRAINING-SILL, or STRUTTING-SILL, a beam that is both a straining-piece and a sill.

STRAP, (from the Dutch, *stroppe*,) in carpentry, an iron plate placed across the junction of two or more timbers, either branched out or straight, as may be found requisite, and each branch bolted, or keyed, with one or more bolts, or keys, through each of the timbers, for the purpose of securing them together. When one piece of timber stands upon another, so as to form two right angles on the same side of the standing-piece, the strap is most frequently made to go round the cross-piece, and to embrace the two opposite sides of the standing-piece, which may be bolted, or keyed, with one or two bolts passing through the tails of the strap. When it is inconvenient to make a strap embrace both opposite sides of the timbers, it is necessary that a branched strap should be placed upon each side, and every timber must be bolted to the opposite branches.

When two pieces of timber press upon each other, and one of them extends on both sides of the joint, a strap is unnecessary: but where neither extends beyond the joint, it is necessary to have one. All ties having shoulders abutting against transverse pieces at the ends, whether the angle formed by the transverse pieces be right or oblique, should be strapped to those pieces.

STRATA, the layers of earth, sand, gravel, clay, chalk, stone, and other substances, which form the crust of the earth. A knowledge of geological strata is very necessary in all extensive building-operations.

STRENGTH OF MATERIALS, the force which any material is capable of resisting before it breaks, whether from pulling, compressing, squeezing, or from being twisted, or from bending by a force applied laterally.

As the laws of resistance are the same, whatever be the material employed, under the specific name of *Strength of Timber*, the reader will find ample satisfaction, at least as far as regards useful knowledge in its application to practical architecture.

STRENGTH OF TIMBER, the resistance that a bar, or beam, is capable of exerting against a superior power, before it breaks, whether the force be applied in its longitudinal or transverse direction, or by twisting. The theory of this subject, illustrated by various examples, will be found in the following Propositions:—

PROPOSITION I.—*The force which elastic strings, or fibrous bodies, &c. exert, when drawn or compressed in a direction of their length, is proportional to the increased or contracted space to which they are lengthened or shortened.*

As the extension or contraction of bodies, when drawn out or compressed by superior forces, depends entirely on the law of corpuscular attraction; and as this law has not yet been developed, it does not, therefore, come within the limits of demonstration: but from numerous experiments on different elastic bodies, it has been sufficiently proved, that when these bodies have been stretched by forces at each end, the additional lengthening was always as the force applied, except when near the point of breaking, where the force was something less than in that proportion; and when compressed by forces, this law has been found to hold equally, except where the compressing forces were enormous; in which case, the contracted spaces were less than the proportion of the force; the truth may, therefore, be looked upon as sufficiently established.

Remark.—Dr. Robert Hook was the first who attended to this subject, and assumed this law as a property of bodies.

PROPOSITION II.—*If a beam be supported at the two ends, and a force, or weight, applied to the middle of it, the deflection of the beam, or space through which it bends, will be as the force applied, nearly.*

This proposition may be determined from the law of elasticity and attraction, supposing them once established; but, perhaps it will be more easily determined by experiment; and the analogy is the same with regard to the deflection in this, as it is in the preceding Proposition, with respect to the increase or decrease of length; and it is found also in this, as in the extended state of the other, that when the beam is nearly upon the point of breaking, a less proportion of weight is required, than the space through which the beam descends. Therefore this Proposition may also be looked upon as sufficiently established.

PROPOSITION III.—*If a solid be supported by four forces, of which two and two are parallel: then, in each pair of parallel forces, one force is equal to the other, and its direction contrary.*

Plate I. *Figure* 3.—Let A B C D represent the section of a solid, supported in the plane of its section, in the parallel directions A G, C P, and A F, C S, by four forces, H, P, I, L, three of which may be weights going over the pulleys G, F, S. Join A C; then let the weight P be represented by the part C M, and complete the parallelogram C M N O; make A R equal to O C; produce G A to K; and complete the parallelogram A K R Q. The point C is now sustained by the three forces, C O, C N, C M, and the point A by the three forces A Q, A R, A K; and the forces A R and O C being equal, and opposite in the same straight line, they mutually balance each other. Now the triangles A K R and O N C are similar, and A R is equal to O C; therefore A K and O N are equal; that is, A K is equal to C M, as A Q is to C N; but A K and C M are the forces at H, as P and A Q and C N are the forces at I and L; therefore the forces at H and P are equal to each other, as are also the forces at I and L. Now, as the string C P is in a state of tension, and as any two of the three angles P C S, S C A, A C P, are greater than two right angles, the lines C S and C A are in a state of tension; and because A C is in a state of tension, A G and A F are so likewise; because any two of the three angles G A F, F A C, C A G, are greater than two right angles therefore the forces in each pair of parallel lines, A G, C P, A F and C S, act equal and contrary to each other.

Corollary.—If the body be a prism, and A B C D a section parallel to one of its faces; and if the directions of the forces be in the lines A B, B C, C D, D A, then the force at P, or the contrary force at H, is to the force L, or its contrary force I, as the breadth of the prism to the length; for as the triangles O N C and A D C are similar, O N : N C : : A D : D C.

Definition.—*Power* is the weight, or force, employed to

break a beam.—*Momentum of Power, mechanical energy*, or *stress, upon a given section of a solid*, the force which a power has to produce fracture at that section, which forms the fulcrum of a lever acted upon by such power.

Corollary.—Hence the strain is as the momentum of power.

PROPOSITION IV.—*If, instead of the weights* I, L, H, *as in the last Proposition, the points* A *and* D, *Figure* 4, *be supported by two springs,* A G *and* D H, *in the direction* A B *and* D C, *parallel to the horizon, and by a prop* D F, *perpendicular to it; and if* A D *be divided into any two parts,* A E *and* E D, *then will* P . CD = ED . f + EA . f; *that is, the momentum of power is equal to the sum of the momentum of tension and compression, where f is the tension of the upper spring, or the compression of the lower.*

For, by the *Corollary* of the last Proposition, f : P : : CD : DA; therefore P . CD = f . DA; but ED . f + EA . f = AD . f; therefore ED . f + EA . f = P . CD.

Corollary 1.—Hence, if a prismatic rectangular beam, AB CD, projecting from a wall, be loaded with a weight, P, sufficient to balance the resistance of the fibres at the place of fracture; there will be a certain line in that place, on which the beam will turn as on an axis, and all the fibres from that line to the upper surface will be extended in the ratio of their distances, whilst all those below will be compressed in the same ratio towards the lower surface.

Corollary 2.—Hence, if E be the quiescent axis, the forces of all the fibres in a state of tension will be equal to EA . f; and those in a state of compression will be equal to ED . f; their whole resistance, therefore, is equal to EA . f + ED . f, that is, equal to the weight, or power, P, multiplied by its distance, DC, from the wall, the momentum of power.

PROPOSITION V. *Figure* 5.—*If a beam be supported by the two ends,* A, B, *and a weight,* W, *be applied over the middle section,* CD; *then will the momentum of power occasioned by the weight,* W, *to overcome the resistance of the beam, be equal to half the weight,* W, *multiplied into half the length of the beam.*

For the beam is under the same circumstance as if it had been supported by three forces in parallel directions; and because the weight, W, is in the middle of the beam, each of the props must support half of it. Now the part DB may be considered as if acted upon by a power at B, equal to half the weight, W, drawing it upwards, while the other part, AC, is fixed in the same manner as if built in a wall; therefore, by the last Proposition, the force to balance the resistance made by the fibres at the section, C, will be equal to $\frac{W}{2} \times$ DB.

Corollary 1.—Hence, if the weight, W, be given, the strain at C will be as the length, AB.

Corollary 2.—Hence it is also evident, that in beams of the same dimensions of breadth and depth, the strain by their own weight is as the square of the length; because the weight is as the length.

Corollary 3.—The greatest strain is where the weight is applied.

Corollary 4.—If there are two beams, having equal weights placed upon them, so as to divide them into segments of equal ratios, the strain in each will be as its length.

Corollary 5.—Hence the strain in a beam fixed in a wall, from any weight hung to its end, is equal to the strain in a beam of twice the length, with double the weight, supported at the ends.

PROPOSITION VI. *Figure* 6.—*If a beam,* AB, *be supported in four points,* A, B, C, D, *and a weight,* W, *appended to the middle of the part* CD *at* F, *it will carry twice as much as if it were only supported by the two middle points* CD.

For, suppose the beam cut through at the section E, then, by *Corollary* 5 of the last Proposition, the strain at C, from a weight at E, will be equal to the strain in a beam of double the length; therefore it will require the same weight to break the parts EC and ED, at C and D together, when cut at E, as it would when CD is whole, and supported at C and D only: therefore, to break all the three sections C, E, D, at once, it will require twice that weight.

PROPOSITION VII. *Figure* 7.—*If a weight,* W, *or any force, act perpendicular to the length of a beam, supported at the two extremities,* A *and* B, *the strain at the section,* C, *on which the force acts, will be equal to the rectangle of the two segments into the weights, divided by the length; that is, as* $\frac{AC \cdot CB \cdot W}{AB}$.

For, by the property of the lever, AB : AC : : W : the force at B. = $\frac{AC \cdot W}{AB}$; but the strain at C, from a force acting at B, is as the distance and force applied; that is, BC . $\frac{AC \cdot W}{AB}$ = $\frac{AC \cdot CB \cdot W}{AB}$.

Corollary 1.—In beams of equal lengths, the strain at the section, C, is as the rectangle of the two segments and the weight.

Corollary 2.—In beams of equal lengths, having equal weights applied, the strain in each is as the rectangle of the two segments only.

Corollary 3.—If the force applied be in the middle, the strain will be as the square of the length.

Corollary 4.—The greatest strain of a beam is in the middle, because the greatest rectangle is there.

PROPOSITION VIII. *Figure* 8.—*The strain on any section,* D, *of a beam resting on two props,* A *and* B, *occasioned by a second force applied perpendicularly upon another section,* C, *is equal to the rectangle of the two extreme segments into the weight, divided by the length; that is,* $\frac{AC \cdot DB \cdot W}{AB}$, *equal to the strain at* D.

For, by Proposition VII., the strain at C is $\frac{AC \cdot CB \cdot W}{AB}$; but the strain at C is to that at D as BC to BD; therefore, BC : BD : : $\frac{AC \cdot CB \cdot W}{AB}$: $\frac{AC \cdot BD \cdot W}{AB}$ equal to the strain at D.

Corollary 1.—Hence, the strain at D, from a weight, W, placed at C, is equal to the strain at C, from the same weight, W, placed at D.

Corollary 2.—Hence, the strain of a beam at any section, from an equal weight placed upon any other section, is as the rectangle of the two exterior segments directly, and length reciprocally.

Corollary 3.—Hence, in the same beam, from the same weight, the strain at any section, D, by the weight at C, is as the rectangle of the two exterior segments.

PROPOSITION IX. *Figure* 9.—*If a weight be equally diffused throughout any part,* BC, *of a beam,* AD, *the strain at either end,* C, *of the diffused part, is to the strain at the same place, from the same weight being suspended there, as* AB + AC *to twice* AC.

Let the weight of the part BC be represented by W, and conceive W to be accumulated in its centre of gravity, E;

then, by the last Proposition, the strain at C from the weight W is $\frac{AB + \frac{1}{2}BC \cdot CD \cdot W}{AD} = \frac{\overline{2AB + BC} \cdot CD \cdot W}{2AD} = \frac{(AB + AC) \cdot CD \cdot W}{2AB}$; and, by Proposition VII., the strain at C, supposing W to be suspended there, is $\frac{AC \cdot CD \cdot W}{AD}$.

Now, $\frac{(AB + AC) \cdot CD \cdot W}{2AD} : \frac{AC \cdot CD \cdot W}{AD} :: AB + AC : 2AC$.

PROPOSITION X. *Figure* 8.—*The strain of a prismatic beam supported at the two ends,* A *and* B, *by its own weight at any section,* C, *is equal to the rectangle of the two segments into the weight of the beam, divided by twice its length; that is,* $\frac{AC \cdot BC}{2AB}$.

Conceive the parts A C and C B of the beam to be accumulated in their centres of gravity, F and G. Let W equal the weight of the whole beam; the weight of the part A C will be $\frac{AC \cdot W}{AB}$, and the weight of the part B C will be $\frac{BC \cdot W}{AB}$. By Proposition VIII., the strain at C, from the weight of the part, A C, is $\frac{AF \cdot CB}{AB} \times \frac{AC \cdot W}{AB} = \frac{AF \cdot CB \cdot AC \cdot W}{AB^2}$, and the strain at C, from the weight of the part B C, is $\frac{GB \cdot AC}{AB} \times \frac{CB \cdot W}{AB} = \frac{GB \cdot AC \cdot CB \cdot W}{AB^2}$.

Therefore the whole strain at C will be $\frac{AF \cdot CB \cdot AC + GB \cdot AC \cdot CB}{AB^2} \times W = \frac{(AF + GB) \cdot AC \cdot CB \cdot W}{AB^2}$.

Now, $AF + GB = \frac{AB}{2}$; therefore, the whole strain by the whole weight, is $\frac{AC \cdot BC \cdot W}{2AB}$.

Corollary 1.—Hence, the strain of a beam at any point, C, from a weight suspended there, is double what it would be at the same point, C, from the same weight being uniformly distributed over it; because, by Proposition VII. the stress is $\frac{AB \cdot BC \cdot W}{AB}$, and by Proposition X. it is $\frac{AB \cdot BC \cdot W}{2AB}$.

Corollary 2.—Because, in the same beam, W and A B being given, the strain at any point, C, is as rectangle of the two segments A C and C B.

THE SAME BY FLUXIONS.

Let $w = W$, equal to the whole weight of $a = AC$, $b = BC$, $l = AB$, and x any indeterminate part, A P. Then the weight of $AP = \frac{w\,x}{l}$, and the fluxion of $\frac{w\,x}{l} = \frac{w\,\dot{x}}{l}$ equal to the weight acting at P. Then, by Proposition VIII., the strain at C, from a weight acting at P, is $\frac{b\,x}{l} \times \frac{w\,\dot{x}}{l} = \frac{b\,w\,x\,\dot{x}}{l^2}$; therefore, by taking the fluent, the strain at C, from the whole weight of A P is $\frac{b\,w\,x^2}{2\,l^2}$. So the strain at C, from the weight of B C, will be found to be $\frac{a\,b^2\,w}{l^2}$; therefore, the whole strain tending to break the beam at C is $\frac{b\,a^2\,w + a\,b^2\,w}{2\,l^2} = \frac{\overline{a + b} \times a\,b\,w}{2\,l^2}$; but $a + b = l$; therefore, $\frac{a + b \times a\,b\,w}{2\,l^2} = \frac{a\,b\,w}{2\,l} = \frac{AC \times CB \times W}{2AB}$.

PROPOSITION XI. *Figure* 10.—*If a prismatic beam,* A B, *be fixed in a wall at* A; *the strain at any section,* C D, *from its own weight will be as the square of the distance,* B C, *of that section from the extremity.*

The strain which the weight of the part B C occasions at the section C D, is the same as if the whole weight of B C were collected in its centre of gravity, F, and the length of the lever, C F.

Let W represent the whole weight of A B; then, because the beam is prismatic, the weight of the part B C will be $\frac{BC \cdot W}{AB}$; therefore, by Proposition IV., *Corollary* 2, the strain at C is $CF \times \frac{BC \cdot W}{AB} = \frac{BC}{2} \times \frac{BC \cdot W}{AB} = \frac{BC^2 \cdot W}{2AB}$; but in the same beam, W and 2 A B are given quantities, consequently, the strain at the section C D is as BC^2.

PROPOSITION XII. *Figure* 11.—*To determine the relative strength of a rectangular prismatic beam,* A B C D, *projecting horizontally from a wall, supposing the beam to be incompressible at the fulcrum.*

Let A B C D be considered as a longitudinal section, and let A B be the section of fracture; let A B C be considered as a bent lever, whose fulcrum is at B; A B, B C, the two arms; and P the power employed to overcome all the resistances in the section A B. Now, in the act of breaking, all the fibres in A B will be stretched, and this the more in the same ratio as they are more remote from the axis of fracture passing through B; and those at A will break first. Let f be a force just sufficient to destroy the cohesion of a fibre: also, let l equal the length, d equal the depth, b equal the breadth or horizontal dimension, and x equal any indeterminate distance from B; then, because the tension of any fibre is as its extension (by Proposition I.) and the extension as the distance of the fibre from the axis of fracture, $d : x :: f : \frac{f\,x}{d}$ the force or tension of a fibre; therefore, the force of all the fibres in the breadth is, $\frac{f\,b\,x}{d}$; but the momentum of any force applied to a lever, is that force multiplied by its distance from the fulcrum, consequently, $\frac{f\,b\,x}{d} \times x = \frac{f\,b\,x^2}{d}$, the momentum of the fibres in the breadth; and the sum of all these momenta upon the lever x is the fluent of $\frac{f\,b\,x^2\,\dot{x}}{d} = \frac{f\,b\,x^3}{3\,d}$; and when $x = d$ $\frac{f\,b\,x^3}{3\,d} = \frac{f\,b\,d^3}{3}$; now, the momentum of the power is P l, therefore, $P\,l = \frac{f\,b\,d^2}{3} = b\,d^2 \times \frac{f}{3}$, or $P = \frac{b\,d^2}{l} \times \frac{f}{3}$.

THE SAME WITHOUT FLUXIONS.

The momentum of the fibres in the breadth is $\frac{f\,b\,x^2}{d}$ as above; but $\frac{b\,x^2}{a}$ is the section of a pyramid, having b and d for the dimensions of its base, and for its altitude a, at the

distance x from the vertex; now, the sum of all the $\frac{b\,x^2}{a}$, in the altitude d of the pyramid, is equal to the whole pyramid; but every pyramid is one-third of a prism, having the same base and altitude, or it is equal to one-third of the base multiplied by its altitude, namely, $\frac{b\,d}{3} \times a$; that is, d times $\frac{b\,d}{3}$ are equal to the sum of as many times $\frac{b\,x^2}{d}$; consequently, the sum of all the $\frac{f\,b\,x^2}{d}$, or the whole momentum of resistance, is $\frac{f\,b\,d^2}{3}$, as above; therefore, P $l = \frac{f\,b\,d^2}{3} = b\,d^2$, or $\text{P} = \frac{f\,b\,d^2}{3\,l} = \frac{b\,d^2}{l} \times \frac{f}{3}$.

Corollary 1.—Because $\text{P} = \frac{b\,d^2}{l} \times \frac{f}{3}$, and $\frac{f}{3}$ is a given quantity, P is as $\frac{b\,d^2}{l}$; that is, the power is as the breadth and duplicate ratio of the depth directly, and length reciprocally.

Corollary 2.—Because P $l = b\,d^2 \times \frac{f}{3}$, and $\frac{f}{3}$ is a given quantity, P l will be as $b\,d^2$; that is, the power, or weight, multiplied by the length, is as the breadth multiplied by the square of the depth.

Corollary 3.—In square timber, the power multiplied by the length is as the cube of the breadth or depth.

Corollary 4.—Because $\text{P} = \frac{b\,d^2}{l} \times \frac{f}{3}$, and $\frac{f}{3}$ are given, the force, or power, required to break similar prisms is as the square of their corresponding dimensions.

Proposition XIII. *Figure* 11.—*To determine the relative strength of a prismatic rectangular beam, projecting horizontally from a wall, supposing it to turn round some intermediate axis, in the section of fracture.*

Let A B C D be a longitudinal section of the beam, parallel to two vertical sides; now it has been shown, by Proposition IV. *Corollary* 1, that here is a certain line passing through some point, E, on which the beam turns in the act of bending, or breaking: that all the fibres above this line are in a state of tension, while those below are in a state of compression; and that the compression or extension of any fibre is as its distance from that line; it also appears, that P . C B = A E . f + E B . f; where f is the whole force of extension or compression. Let m equal the extension of a fibre in the upper part, at the instant of breaking; n equal the compression of a fibre in the lower surface at the same instant; and let b equal the breadth of the beam; a = A E, e = E B, l = B C, x = any indeterminate part of A E, or a, from E towards A: then, since, by Proposition I. the force of a fibre is as the distance to which it is extended or compressed, $a : m :: x : \frac{m\,x}{a}$, the force of a fibre at the distance x; but the energy, or resistance, of this force, is as the length of the lever, x, upon which it acts; consequently, as $\frac{m\,x^2}{a}$, and the sum of all the resistances in the breadth, is $\frac{m\,b\,x^2}{a}$, the whole resistance of the extended fibres in x is the fluent of $\frac{m\,b\,x^2\,\dot{x}}{a} = \frac{m\,b\,x^3}{3\,a}$; and when $x = a$, then $\frac{m\,b\,x^3}{3\,a} = \frac{m\,b\,a^2}{3}$. In the same manner, it may be shown, that the sum of all the resistances of the compressed fibres is $\frac{n\,b\,e^2}{3}$, and, therefore, the whole sum of all the extended and compressed fibres is $\frac{m\,b\,a^2 + n\,b\,e^2}{3} = \text{A E} \,.\, f + \text{E B} \,.\, f = l\,\text{P}$.

Now, if the ratio of m to n be known, that of a to e will also be known; for $f\,a = \frac{m\,b\,a^2}{3}$, $f = \frac{m\,b\,a}{3}$, and $f\,e = \frac{n\,b\,e^2}{3}$. $f = \frac{n\,b\,e}{3}$, therefore $\frac{n\,b\,e}{3} = \frac{m\,b\,a}{3}$, or $n\,e = m\,a$, consequently, $n : m :: a : e$. Hence, it will be seen, that the distance of the axis of fracture depends on the nature of timber. Now, let $d = a + e$, the depth of the beam, and let a and e be equal to each other, then will m and n be also equal to each other; and $\frac{m\,b\,a^2 + n\,b\,e}{3} = \frac{m\,b\,d^2}{6} = \frac{m}{6} \times b\,d^2 = \text{P}\,l$, or $\text{P} = \frac{b\,d^2}{l} \times \frac{m}{6}$.

It will readily appear, that all the Corollaries in the preceding Propositions will equally flow from this; it may, nevertheless, be observed, that the relative strength of such beams as are equal rectangular prisms of homogeneous texture, upon supposition, is only one-half of what is expressed in the former.

The celebrated Galileo, who first undertook the discovery of the law of resistance, supposes that at the place of fracture the body breaks at once, so that the whole of the fibres resist with their ultimate force: a supposition that would be correct, were the matter of bodies of a homogeneous and unelastic texture.

Mariotte, an eminent French philosopher and mathematician, who first corrected the Galilean notion of equal resistances made by the fibres of a beam at the section of fracture, having observed that all bodies bend before they break, considered the fibres as so many bent springs, which never exert their utmost force till stretched to a certain distance. But the axis of fracture was still considered as in the convex side of the beam. Now, as it has been shown, that timber in a state of bending, or breaking, is both compressed and extended, it follows that this axis cannot be in the convex surface, but must have some indeterminate situation between the upper and lower superficies. To compare the three suppositions with each other: in the act of breaking, the resistance of a fibre, according to Galileo, is a constant force in the section of fracture; therefore, let f denote the force of a fibre, then its momentum will be $f\,x$, and the sum of all the $f\,x$ will be the fluent of $f\,x\,\dot{x} = \frac{f\,x^2}{2}$, and the sum of all the $\frac{f\,x^2}{2}$ in the breadth will be $\frac{f\,b\,x^2}{2}$; and when $x = d$, the depth, $\frac{f\,b\,x^2}{2} = \frac{f\,b\,d^2}{2}$, for the relative strength. Now, it has been shown in Proposition XII., which is that of Mariotte, that the relative strength is $\frac{f\,b\,d^2}{3}$, and by Proposition XIII., it is $\frac{f\,b\,d^2}{6}$, by substituting f for m; but $\frac{f\,b\,d^2}{2}$, $\frac{f\,b\,d^2}{3}$, and $\frac{f\,b\,d^2}{6}$, are to

each other as 3, 2, 1; hence, the relative strength of beams, according to the system of Mariotte, is two-thirds of Galileo's; while, according to the supposition of the axis fracture being in the middle of the beam, the relative strength is only one-third of Galileo's, or half of Mariotte's.

It is worthy of notice, that, although the relative strength is very different on the three suppositions, yet in each it is as the breadth, duplicate ratio of the depth, and reciprocal ratio of the length. This relation is the most important; and, if exactly true, would answer every purpose: for, by having the weight that a piece of timber of any given dimensions will carry, that which a piece of timber of any other given dimensions would bear, might be ascertained, without paying any attention to the absolute strength.

A very commodious formula may be had from this analogy, as follows:—

Suppose a piece of timber, a foot in length and an inch square, would carry w pounds; let l be the length of any other piece of timber in feet, b the breadth, and d the depth in inches; and let w be the weight in pounds that these dimensions will carry; then $w = \frac{b\,d^2\,w}{l}$, for, by this analogy, $\frac{1 \times 1^2}{1}$, or $1 : \frac{b\,d^2}{l} :: w : w$; therefore, $w = \frac{b\,d^2\,w}{l}$.

That is, the strength of any piece of timber is equal to the relative strength of a piece of timber a foot in length and an inch square, multiplied into the breadth and square of the depth, divided by the length.

Example.—Suppose a piece of timber a foot in length and an inch square, would carry 500 pounds, how much will a piece eight feet in length and five inches square carry? Here $w = 500$, $b = 5$, and $d = 5$; therefore,

$$\frac{b\,d^2\,w}{l} = \frac{5 \times 5^2 \times 500}{8} = 7812.5.$$

In pieces of timber of the same length, the relative strength, being as the breadth and square of the depth, differs but in a very small degree from that which actual experiment gives; but in order to show how far the practical carpenter may confide in the rule just found from the theory, we have two sets of experiments, made on oak timber, one by the celebrated French engineer Belidor, on a small scale, the other by M. De Buffon, much more extensive, with which the result found by rule may be compared. The pieces tried by Belidor were sound, evenly-grained oak, and tolerably well seasoned; and the relative strength resulting from the various dimensions tried, are exhibited in the following Table; where, it must be observed, the lengths are in the second vertical column, under L, on the left, and the other dimensions in the columns under the initials B and D. The weight required to break the beams is given in lbs. in the fifth column. Three pieces of each dimensions were tried, and the mean taken. The experiments were of two kinds; one set with the ends loose, the other with the ends firmly fixed.

In the following table—

No. 1 and 2 show the strength to be as the breadth.

No. 1 and 3, as the square of the depth.

No. 1 and 4, nearly as the reciprocal of the length.

No. 4 and 5, nearly as the breadth multiplied into the square of the depth.

No. 1 and 5, nearly as the breadth multiplied into the square of the depth, divided by the length.

The two lower numbers, 7 and 8, show the increase of strength derived from fastening the two ends. By comparing No. 1 with No. 7, and No. 4 with No. 8, the strength of the loose bar to that of the fixed one, appears to be in the ratio of 2 to 3; but the theory shows it to be in the ratio of 1 to 2, that is, as 2 to 4; though a difference in the manner of fixing may produce this deviation.

Table I.

N.	L.	B.	D.	lb.	Medium.	
1	18	1	1	400 415 405	406	Ends loose.
2	18	2	1	810 795 812	805	
3	18	1	2	1570 1580 1590	1580	
4	36	1	1	185 195 180	187	
5	36	2	2	1550 1620 1585	1585	
6	36	1⅜	2½	1665 1675 1640	1660	
7	18	1	1	600 600 624	608	Ends fixed.
8	36	1	1	285 280 285	283	

The following Table is an abstract of experiments on beams of four inches, by Buffon. The first column contains the length of the bar in the clear, between the props. The second, the weight of the bar, the next day after it was felled, in pounds. The third column exhibits the number of pounds necessary for breaking it in the time shown by the fifth column. Column the fourth shows the inches bent in the act of breaking; and the fifth, the time required to break each beam. Two bars of each length were tried, and each of the first three pairs were cuts of the same tree.

Table II.—*Experiments on Beams Four Inches Square.*

Length of Bar in Feet.	Weight of Bar in lbs.	lb. to break Bar.	Inches bent in breaking	Time in breaking
7	69	5350	3.5	29
	56	5275	4.5	22
8	68	4600	3.75	15
	63	4500	4.7	13
9	77	4100	4.85	14
	71	3950	5.5	12
10	84	3625	5.83	15
	82	3600	6.5	15
12	100	3050	7.	
	98	2925	8.	

The cut next to the root was always found to be the heaviest, stiffest, and strongest; and from this invariable coincidence of weight and strength, M. De Buffon recommends, as an unerring rule, to make choice of timber by its weight. He finds, that this was always the case when timber had grown vigorously, forming thick annual layers; but observes, that this is only during the advances of the tree to maturity; for the strength of the different circles approaches gradually to an equality, during the healthy growth of the tree.

M. De Buffon also made experiments on other sizes of timber of a square section. Thr medium of two pieces of the same length and section were taken; and the following Table exhibits the results of those mediums. The lengths are contained in the vertical column on the left hand, and the dimensions of the section, or scantling, are expressed at the top, in inches.

The experiments on the five-inch bars were considered, by M. De Buffon, as a standard, he having both extended their number, and tried other pieces of the same length. He found, after repeated trials, that oak timber lost much of its strength in seasoning, to secure uniformity; and therefore, he caused it all to be felled at the same time of the year, squared the day after, and tried on the third day; which gave him an opportunity of observing a very curious phenomenon. For when the weights were laid quickly, and were nearly upon the point of breaking, a sensible smoke was observed to issue from the ends with a sharp hissing noice, which continued while the beam was bending. This evidently shows, that it must have been compressed throughout its whole length.

Table III.

L.	4 In.sq.	5 In.sq.	6 In.sq.	7 In.sq.	8 In.sq.
7	5312	11525	18950	32200	47649
8	4550	9787½	15525	26050	39750
9	4025	8308½	13150	22350	32800
10	3612	7125	11250	19475	27750
12	2987½	6075	9100	16175	23450
14		5300	7475	13225	19775
16		4350	6362½	11000	16375
18		3700	5562½	9245	13200
20		3225	4950	8375	11487½
22		2975			
24		2162½			
28		1775			

In the above Table, the weight of the beams is not taken into the account; therefore, to make a just comparison with the theory, it will be necessary to add half the weight of each beam to itself. The half-weights will be found in the following Table, in the same manner as in the preceding; the lengths being contained in the first vertical column, and the dimensions of the section at the top.

Table IV.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	28.777	44.965	64.750	88.131	115.111
8	32.888	51.388	74.000	100.722	131.555
9	37.000	57.812	83.250	113.312	148.000
10	41.111	64.236	92.500	125.902	164.444
12	49.333	77.083	111.000	151.083	197.333
14		89.930	129.500	176.263	230.222
16		102.777	148.000	201.444	263.111
18		115.625	166.500	226.625	296.000
20		128.472	185.000	251.805	328.888
22		141.269			
24		154.166			
28		179.861			

The numbers in the above Table, added to the preceding, give the following, omitting the decimals.

Table V.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	5340	11570	19014	32288	47764
8	4582	9838	15599	26150	39881
9	4062	8365	13233	22463	32948
10	3653	7189	11342	19600	27914
12	3036	6152	9211	16326	23647
14		5389	7604	13401	2005
16		4452	6510	11201	16638
18		3815	5728	9471	13496
20		3353	5135	8626	11815
22		3116			
24		2316			
28		1954			

By taking the weights in the above Table, corresponding to the seven-feet lengths as a standard, the following Table may be calculated, by making the succeeding weights follow in the reciprocal ratio of their lengths.

Table VI.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	5340	11570	19014	32288	47764
8	4672	10123	16637	28252	41793
9	4153	8998	14788	25112	37149
10	3738	8099	13309	22601	33434
12	3115	6749	11091	18834	27826
14	.....	5785	9507	16144	23882
16	.....	5061	8318	14126	20897
18	.....	4499	7394	12556	18574
20	.....	4049	6654	11300	16717
24	.....	3681	.....	.....	.....
28	.....	3374	.....	.....	.....

By comparing this table with the fifth, it will be found, that the strength of beams decreases in a ratio much more than that of the reciprocal ratio of the length; and it would also appear, that the greater the dimensions, the more rapid will the decrease be; for, taking any two numbers as a ratio of any given dimension of section, belonging to any two different lengths, and comparing them with that of a greater dimension of section immediately following, of the same length, the fourth number resulting will be greater than that which is found by experiment, thus:
11570 : 3352 : : 19014 : 5510, which should only be 5135;
19014 : 5135 : : 32288 : 8719, which should only be 8626; and
32288 : 8626 : : 47764 : 12760, which should only be 11815.

The preceding theory will not account for this great deviation from rule. It is probably owing to our ignorance of the law of attraction, by which the particles of fibres are held together, and of the law by which the fibres slide longitudinally on each other; but in order to show this more particularly, all the five-inch bars in Table V., as far as the twenty-feet lengths, are taken as standards, and a set of numbers are found in proportion to the cubes of the sides of their sections; the result of these calculations are exhibited in the following Table: where the sign + subjoined to any number, shows that an addition is to be made to the number, in order to make it equal to that found by experiment; and in like manner, the sign — subjoined to any number, indicates a deduction to be made from that number.

Table VII.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	5923—	11570	19992+	31748+	47320+
8	5037—	9838	17000—	26995—	40296—
9	4282—	8365	14454—	22953—	34263—
10	3680—	7189	12422—	19726—	29446—
12	3149—	6152	10630—	16881—	25198—
14	.....	5389	9312—	14787—	22073—
16	.....	4452	7692—	12216—	18235—
18	.....	3815	6592—	10468—	15626—
20	.....	3353	5793	92000—	13734—

The columns in the succeeding Table contain the differences between the above and Table V. of experiments, corrected by the half-weights; the + shows that the number to which it is prefixed, is to be added to that found by rule, and the sign — denotes, that the number to which it is prefixed, is to be abstracted from what is found by rule.

Table VIII.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	—573	000	— 978	+ 540	+ 374
8	—455	000	—1401	— 845	— 415
9	—220	000	—1221	— 490	—1315
10	— 27	000	—1080	— 126	—1532
12	—113	000	—1419	— 555	—1551
14	.....	000	—1708	—1386	—2068
16	.....	000	—1182	—1015	—1597
18	.....	000	— 864	— 997	—2130
20	.....	000	— 574	— 574	—1919

By comparing the different lengths of the five-inch beams with those of the other scantlings, they will be found to be much too strong; for the numbers in the other columns are all in excess, except two: but by reducing the five-inch bars about the twentieth part of their strength, a set of numbers may be calculated, not greatly differing from those found by experiment. In each of the succeeding horizontal columns, the excess of those found by rule, at an average, is continually greater than what is given by experiment; which shows that the different lengths have an effect upon the strength, and, therefore, in two pieces of the same length, the relative strength is not in the same proportion as in two other pieces of different lengths, but of the same dimensions of section. Hence, as the length is greater, the strength, in advancing from a less dimension to a greater, is continually less than that of the cube of their sides. Experiments on timber are too few, and too anomalous, to afford any certain means of correction.

It has been found, that by adding 1245 to each of the weights in the column of five-inch bars, a set of numbers may be generated nearly in the proportion of the inverse ratio of the lengths; and, therefore, if s denote the relative strength, w the weight found by experiment necessary to break a beam of five inches square, L its length, and l the length of any other beam; the strength of this latter will be expressed by $\frac{w + 1245 \times L}{l} - 1245$. From this formula, by making $L = 7$, and $w = 11570$, the weight found, by experiment, necessary to break the seven-inch beam, the numbers in the following Table have been calculated. The first column contains the lengths; the second, the result of calculation; the third, the weight found to break each beam, taken from Table V.; and the fourth, the difference between those found by rule, and those given by experiment.

Table IX.

1st.	2nd.	3rd.	4th.
7	11570	11570	0
8	9968	9838	130
9	8722	8365	357
10	7725	7189	536
12	6230	6152	78
14	5162	5389	227
16	4361	4452	91
18	3738	3815	77
20	3240	3353	113
22	2832	3116	284
24	2492	2316	176
28	1958	1954	4

From the above rule, which is only applicable to the five-inch bars, another more general one has been derived; which is, $s = \frac{651\ b\ d^2}{l} - 10\ b\ d^2$.

This formula is founded on the following observations: a constant number may be added to each column, which will increase the numbers therein contained in the reciprocal ratio of their lengths: the constant additive number of one column is to that of another as the cube of the side of the beams of the former to the cube of the side of the beams of the latter; therefore, $5^3 : 1^3 :: 1245 : 9.96$, or 10 nearly, for the additive number to a bar of an inch square. Again, $5^3 : 4^3 :: 1245 : 6.37$, or 6.40 nearly, for the additive number to a beam of four inches square; consequently, the relative strength of a piece of a foot in length, and an inch square, taking 5312 for a radical number, is $\frac{5312 + 640 \times 7}{64} - 10 = 641$.

The relative strength of a piece in general will, therefore, be $\frac{651\ b\ d^2}{l} - 10\ b\ d^2$, or, in square beams, $\frac{651\ b^3}{l} - 10\ d^3$.

Example.—What weight will be required to break an oak beam twenty feet long and eight inches square?

$$\frac{651 \times 8^3}{20} - 10 \times 8^3 - 11545.$$

That the reader may judge properly of the application of this rule, the following Tables have been calculated. The first contains the numbers according to calculation; the second, the differences between the first Table and the Table of experiments; where it may be observed, that six, seven, and eight-inch beams differ less and less from the experiment, as the beams are longer: the greatest difference is in the seven-inch beam of seven feet long, which is something greater than one-ninth, and less than experiment.

This rule is sufficiently exact for practical purposes, as in most cases it gives a solution within the fifteenth part of what would result from experiment: though the principle upon which it is founded cannot be admitted to be just, for when the length is 65.1 the quantity $\frac{651\ b\ d^2}{l} = 10\ b\ d^2$, and, consequently, the strength would be nothing.

Table X.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	5312—	10375+	17928+	28469+	42496+
8	4568—	8925+	15417—	24481+	36544+
9	3989—	7791+	13464—	21380+	31914+
10	3526+	6887+	11901—	18899+	28211—
12	2832+	5531+	9558—	15177+	22665+
14	.....	4462+	7884—	12519+	18688+
16	.....	3835+	6628—	10525+	15712+
18	.....	3270+	5652—	8975+	13397—
20	.....	2818+	4870+	7734+	11545—
22	.....	2448+	.....	.....	.....
24	.....	2140+	.....	.....	.....
28	.....	1656+	.....	.....	.....

Table XI.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	0	+1150	+1022	+3731	+5153
8	+ 18	+ 866	+ 108	+1569	+3206
9	+ 36	+ 517	— 314	+ 970	+ 886
10	+ 86	+ 238	— 651	+ 576	+ 461
12	+ 155	+ 544	— 458	+ 998	+ 794
14	.....	+ 738	— 409	+ 706	+1087
16	.....	+ 515	— 266	+ 475	+ 663
18	.....	+ 430	— 90	+ 270	— 197
20	.....	+ 407	+ 80	+ 641	— 58
22	.....	+ 527	.....	.....	.....
24	.....	+ 22	.....	.....	.....
28	.....	+ 119	.....	.....	.....

The succeeding Table is calculated upon other principles, viz. that the strength is as the breadth and square of the depth, and reciprocally as the fourth root of the fifth power of its length; and that the mean relative strength of a bar of oak, one foot in length, and an inch square, is found to be 1,000 lb. nearly; therefore, let s be the relative strength of a piece of timber, b the breadth, and d the depth; then $s = \frac{1000\ b\ d^2}{l^{\frac{5}{4}}}$. This formula is exceedingly easy; and the arithmetical operation will be much simplified by the use of logarithms. The radical number, 1000, is founded on Buffon's experiments, and is reduced to a piece of one foot long and

an inch square, by the last given note. Mr. Emerson says, a piece of good oak, an inch square and a yard long, supported at both ends, will bear in the middle, for a very little time, 330 lb. avoirdupoise, but will break with more than that weight: now, upon the supposition that the strength is reciprocally as the length, the section being the same, 1 : 3 : : 330 : 990, for the strength of a piece of oak one foot long and an inch square, which is nearly 1000 lb., but as $3\frac{5}{4}$ is greater that 3, and almost equal to 4, we have $330 \times 4 = 1320$, instead of 1000; so that Emerson's timber is stronger than Buffon's.

Table XII.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
$7\frac{5}{4}$	5621—	10978+	18970+	30125+	44968+
$8\frac{5}{4}$	4756—	9290+	16054+	25494+	38055+
$9\frac{5}{4}$	4105—	8018+	13856—	22003+	32845—
$10\frac{5}{4}$	3599+	7029+	12146—	19288+	28792—
$12\frac{5}{4}$	2865+	5596+	9671—	15357+	22925—
$14\frac{5}{4}$		4615+	7976—	12665+	18908—
$16\frac{5}{4}$		3906+	6750—	10715+	16000—
$18\frac{5}{4}$		3371+	5826—	9251+	13810—
$20\frac{5}{4}$		2955+	5107+	8109+	12105—
$22\frac{5}{4}$		2623+	.....	.....	.....
$24\frac{5}{4}$		2353+	.....	.....	.....
$28\frac{5}{4}$		1939+	.....	.....	.....

The succeeding Table contains the differences between the above and the Table of experiments: most of them are within the fifteenth part of the truth, excepting those of the five-inch bars, marked with a star: that column, as has been observed, appears to have much stronger timber than the others.

Table XIII.

L.	4 In. sq.	5 In. sq.	6 In. sq.	7 In. sq.	8 In. sq.
7	— 281	+ 592	+ 44	+ 2163	+ 2796
8	— 174	+ 548	— 455	+ 656	+ 1826
9	— 43	+ 347	— 623	+ 460	+ 103
10	+ 54	+ 160	— 804	+ 312	+ 878
12	+ 171	+ *556	— 460	+ 969	+ 722
14		+ *774	— 372	+ 736	+ 1097
16		+ *546	— 240	+ 486	+ 638
18		+ *444	— 98	+ 220	— 314
20		+ *398	+ 28	+ 517	— 290
22		+ *493	.....	.....	.....
24		+ 37	.....	.....	.....
28		+ 15	.....	.....	.....

M. De Buffon uniformly found, that two-thirds of the weight necessary to break a piece of timber, in a few minutes impaired its strength, and frequently broke it at the end of two or three months: the half of that weight brought it to a certain degree of curvature, which did not increase after the first minute or two; and this, he found, might be borne for any length of time; but when the weight was removed, the timber had acquired a curvilinear figure. One-third of the weight appeared to have no effect; and, when properly seasoned, the timber recovered its rectilinear figure, after being loaded several months. Therefore, when the strength of a piece of timber is known, according to any of the preceding methods, and if it is applied to any mechanical purpose, in bearing or supporting a heavy body, it ought to have sufficient strength to bear thrice, or rather four times, the weight to be applied.

Several reasons may be assigned for the irregularity of experiments; some pieces, even from the same tree, might be much stronger than others. M. De Buffon says, that healthy trees are always strongest at the root. The ligneous coats might not be disposed in the same way, and their resistance is always greater when perpendicular to the force applied, than when in an horizontal direction. The trunk of a tree is composed of many hollow cylinders, each formed in the annual growth; these are only united by a soft medullary substance; and when the tree is brought to a square, or cut into beams, the portions of the ligneous cylindric coats at the angles, present but a very small resistance.

A bar of small size, such as an inch square, cut out of a large tree, may have its annual plates nearly in planes, disposed perpendicularly to one of its sides, and, consequently, it will be as much stronger, or weaker, than the largest square beam cut out of a tree of the same size and texture, as the force is applied to the side, or edges, of the plates. M. De Buffon found, from repeated trials, that the strength of a bar, with its plates in the direction of the breaking force, was to that of a bar with its plates perpendicular to it, as 8 to 7, nearly.

From what has been said, and exhibited in the foregoing Tables, it appears that the resistance of timber increases in a ratio somewhat less than the square of the depth, and somewhat greater than in the reciprocal ratio of the length.

The cohesion of timber is probably of a nature different from that of metal, and is subject to greater inequalities: which inequalities are occasioned either by the soil in which the tree was reared, the growth of the tree, or the part from which it is cut.

To what has already been said, the following practical remarks may be added.

Mr. Petit, on the authority of his own experiments, and those of M. Parent, declares that the utmost strength of a square inch of oak, by pulling in the direction of its length, does not exceed 8640 lb., whereas Muschenbroeck makes it 17,300 lb., but by experiments tried at the Royal Military Academy, Woolwich, the strength of oak has been found but little exceeding 9,000 lb., its specific gravity being 774. The writer of the article, Strength of Materials, in Rees's *Cyclopædia*, observes, that "We have not this datum in either of the above cases; yet we conceive it to be a very important one, as we have always found the strength of wood of the same kind, to depend a great deal upon the weight, or specific gravity. The same experiments give for the strength of ash 17,000 lb. and fir from 10,000 lb. to 13,000 lb., both considerably different from Muschenbroeck's tabular results." The same writer, or experimenter, adds, that "an oak rod of an inch surface requires a weight of about 9,000 lb. to

produce fracture; while the same, or a similar rod, fixed in a wall, and acted upon at the distance of a foot, is broken with a weight of 132 pounds."

He farther remarks, that "a beam of fir, 6 feet long and 2 inches square, supported at each end, broke with 744 lb.; and the mean of several experiments of similar pieces of the same dimension, fixed at each end, required 1,105 lb.; while the fragments of the same, 3 feet long, broke with one end in a wall, required at a medium 400 lb."

Upon the experiments of Buffon and Belidor, this writer observes, that "Another discrepancy between theory and experiment is, where the strength ought to be inversely as the length; it shows itself in the above experiments, but is very remarkable in those of M. De Buffon; and though our preceding remarks will explain very satisfactorily this deviation, we are almost afraid to offer it as an illustration, after seeing it treated as an inexplicable paradox by some writers of the first eminence. We have seen that if w be the computed weight, independent of the deflection, the absolute weight will be w cos. D, D being the angle of deflection; and as this deflection, both from theory and practice, is found to increase as the square of the length; it follows, that when the length is quadrupled, the depth of the deflection will be sixteen times greater; that is, the sine of the angle of deflection will be sixteen times more in one case than in the other, while the radius will be only four times longer; and therefore the angle in the one case about four times what it is in the other, (supposing, in a rough way, the angle to vary as the sine). Consequently, if w × cos. D is the weight which breaks the shorter beam, $\frac{1}{4}$ w × cos. 4 D ought to be that which breaks the longer one, and this, we presume, will nearly, if not entirely, account for the decrease of the strength in Buffon's experiments. We cannot perceive but that this reasoning is perfectly legitimate, yet we are astonished that it should not have occurred to so keen a mathematician as the one to whom we have alluded, or to some one of the writers on this subject; and on this account we offer it with some hesitation."

This excellent writer concludes thus: "Our limits will not admit of reporting here the nature of the experiments, nor the calculations founded upon them, which led to this determination; but we hope soon to see them laid before the public in another form. We can only give here the result, which, as far as it is at present ascertained, is as follows:

"The centre of tension and centre of compression are nearly, or exactly, coincident with the centre of gravity; and the neutral line, whatever may be the figure of the section, is so posited, that the rectangle of the area of tension into the distance of its centre of gravity from the said line, is to the rectangle of the area of compression into the distance of its centre of gravity, as 1 to 3.

"From which theorem, the neutral line for any formed beam may be determined, and the absolute strength may then be found as follows, *viz.* Let d denote the distance of the centre of tension, and l the length of the beam, all in inches; D the angle of deflection, and f the strength of direct cohesion on a square inch; then, without considering the increased length of lever,

"1. When a beam is fixed at one end,

$$w = \frac{2fad}{l \cos. D}.$$

"2. When the beam is supported at both ends,

$$w = \frac{8fad}{l} \times \cos. D.$$

"3. When the beam is fixed at both ends,

$$w = \frac{12fad}{l} \times \cos. D.$$

"And when the beam is fixed at one end at any angle, formula I will still apply; only increasing or decreasing the angle of deflection by the quantity of the first angle of inclination, according as that inclination is downwards or upwards.

"And when the beam is supported, or fixed, at both ends, and either resting obliquely, or acted upon by an oblique force, the two latter formulæ become,

"4. For the beam supported at each end,

$$w = \frac{8fad}{l} \times \frac{\cos. D}{\cos. I}.$$

"5. For the beam fixed at each end,

$$w = \frac{12fad}{l} \times \frac{\cos. D}{\cos. I};$$

where I denotes the angle, which the direction of the force makes with the direction of the beam.

"*Note* 1.—It should have been observed, that the preceding theorem for determining the neutral line, is princi pally drawn from experiments on fir beams. A different ratio than 1 : 3 may be necessary in other kinds of wood, but at present that ratio has not been found.

"*Note* 2.—The deflection, D, as we have before observed, is not a necessary datum in estimating the strength of timber, for any practical purposes of building, &c., it is merely introduced in order to reconcile the theory with the result of experiments made upon the absolute and ultimate strength, in which cases, particularly in long beams, it becomes an important quality, and must not be omitted; and in all cases where it is required, it must be drawn from some prior ex periment on the same kind of wood, by means of the following theorem, viz.

"Let l, d, D represent the length, depth, and deflection, of any beam; l', d', the length and depth of any other beam, whose deflection, D', is required; then $D' = \frac{l' d D}{l^2 d'}$.

"*Example* 1.—*The strength of direct cohesion on a square inch of fir being* 13,000 *lb., required the weight necessary to break a rectangular bar,* 30 *inches long,* 2 *inches deep, and* 1 *inch in breadth, when fixed at one end in a wall, and the weight acting at the other: the deflection, computed from other experiments, having been found to be* 5 *inches.*

"First find the neutral line: here, since the section is a rectangle, the centre of tension and compression are each on the centres of their respective areas; therefore call the depth of tension x, the depth of compression will be $2 - x$, which also denote these areas; and we must have, therefore,

$$\frac{x^2}{2} : \frac{(2-x)^2}{2} :: 1 : 3;$$

or $3x^2 = 4 - 4x + x^2$ or $x^2 + 2x = 2$.

Whence $x = -1 + \sqrt{3} = .732 = a$;

also $\frac{.732}{2} = 366 = d$;

tan. of deflection $= \frac{5}{30} = \frac{1}{6} = .16666666$.

When the angle D = 9° 34′, and its cosine = .9860; therefore, by formula 1,

$$w = \frac{2fad}{l. \cos. D} = \frac{2 \times 13{,}000 \times .732 \times .366}{30 \times .986} = 235 \text{ lb.}$$

"*Example* 2.—*Required the weight that would break the same beam, when supported at each end, rejecting the deflection, which is very inconsiderable.*

"By Formula 2,

$$w = \frac{8\,f\,a\,d}{l} = \frac{8 \times 13{,}000 \times .732 \times .366}{30} = 928 \text{ lb.}$$

"*Example* 3.—*Required the weight that would break the same beam, fixed at each end.*

"Rejecting the deflection, we have, by Formula 3,

$$w = \frac{12\,f\,a\,d}{l} = \frac{12 \times 13{,}000 \times .732 \times 366}{30} = 1492 \text{ lb.}$$

"*Note.*—We have assumed 13,000 for the force of direct cohesion; this, however, rather exceeds the greatest strength of fir, which varies from 10,000 to about 13,000 lb.

"*Example* 4.—*Assuming the direct cohesion at* 13,000, *and the specific gravity of fir at* 720; *how long must a beam be, that is two inches deep and one inch broad, which, when fixed, with one end in a wall, will just break with its own weight?*

"Let x be the required length of the beam in inches; its weight will be $\frac{2\,x \times 720}{1728}$ ounces, or $\frac{90\,x}{1728} = \frac{5x}{96}$ pounds; and this weight will have the same effect as if it acted all at one point on the centre of the beam, or at the distance $\frac{1}{2}\,x$.

"Hence, by substituting $\frac{5x}{96}$ for w, in Formula 1, we have $\frac{5x}{96} = \frac{2 \times 13{,}000 \times .732 \times .366}{\frac{1}{2}x}$; or $5\,x^2 = 192 \times 2 \times 13{,}000 \times .732 \times .366 = 133{,}728$; whence $x = \sqrt{\frac{133728}{5}}$ inches, or 47 feet.

"In this case, the angle of deflection is not introduced.

"When the deflection is considered, as it should be in this case, we find it to be, from the data of Example I., and the theorem for the deflection, as $30^2 : 5 :: \frac{1}{4}x^2 : \frac{5\,x^2}{3600}$; whence the cosine $= \sqrt{\left(1 - \frac{25\,x^2}{(1800)}\right)}$; and the above equation becomes $\frac{5x}{96} = \frac{2 \times 13{,}000 \times .732 \times .366}{\frac{1}{2}x\sqrt{\left(1 - \frac{25\,x^2}{(1800)^2}\right)}}$; which produces a cubic equation, whence the value of x may be determined.

"Mr. Banks, after many experiments made, at various times, on the real and comparative strength of oak, fir, and iron, has deduced the following inferences: the worst, or weakest, piece of dry heart of oak, one inch square and one foot long, bore 660 lb., though it was much bent, and 2 lb. more broke it. The strongest piece he tried, of the same dimensions, broke with 974 lb. The worst piece of deal bore 460 lb.; but broke with little more. A bar of the weakest kind of cast-iron, of an inch square and a foot long, would break with 2190 lb.

"The following are some of the experiments he mentions; (see Banks *On the Power of Machines.*)

"*Experiment* 1.—Two bars of cast-iron, once inch square and three feet long, were placed upon a horizontal bar, so as to meet in a cap at the top, from which was suspended a scale; these bars made each an angle of 45° with the base-plate, and of course formed an angle of 90° at the top; from this cap was suspended a weight of 7 tons, which was left for sixteen hours, when the bars were a little bent, but very little.

"*Experiment* 2.—Two bars of the same length and thickness, were placed, in a similar manner, making an angle of 22½° with the base-plate; these bore 4 tons upon the scale; a little more weight broke one of them, which was observed to be a little crooked when first put up. In this case the pressures would be as the sines of the angles of elevation, viz., as 3826 to 7071, and as 3826 : 7071 : : 4 tons : 7.6 tons; that is, if the second bars broke with 4 tons, the first ought to have taken 7.6 tons to break them; and it is likely that such would, if tried, have been the case.

"*Experiment* 3.—Another bar was placed horizontally upon two supporters, exactly three feet distant, which bore 6 cwt. 3 qrs. or 675 lb. but broke when a little more was added.

"*Experiment* 4.—The same experiment repeated with the same result.

"*Experiment* 5.—The bearings were 2 feet 6 inches apart, the bar broke with 9 cwt.

"Three more experiments were tried at three feet, the average result was 6 cwt. 2 qrs. and 6½ lb.

"Mr. Banks made some experiments on the strength of cast-iron, at Messrs. Aydon and Elwell's foundery, Wakefield. The iron came from their furnace at Shelf, near Bradford, and was cast from the air-furnace; the bars, one inch square, and the props exactly three feet distant; one yard in length weighed exactly 9 lb. or one about half an ounce less, the other a very little more; they all bent an inch before they broke.

	lb.
1. The first bar broke with	963
2. The second bar with	958
3. The third bar with	994
4. A bar made from the cupola	864
5. A bar equally thick in the middle, but the ends formed into a parabolic form, weighing 6 lb. 3 oz.	874

"The same gentleman, after many other experiments, concludes from the whole, that cast-iron is from 3½ to 4½ times stronger than oak of the same dimensions, and from 5 to 6½ times stronger than deal.

"We shall only observe here, (says the writer of the STRENGTH OF MATERIALS, in Rees's *Cyclopædia*,) that Mr. Banks's pieces of oak exceed very considerably the specimens we had an opportunity of trying, while his fir falls something short of ours."

The following Tables of Experiments on the strength of various materials under different circumstances will be found useful. They are extracted principally from Tredgold, to whose works, and those of Barlow, we would refer for further information:

Cohesion of a Square Inch, pulled asunder in a direction perpendicular to the Length of the Fibres.

Kind of Wood	Cohesion of a square inch perpendicular to fibres, in pounds.	Experimentalist.
Oak	2316	Tredgold.
Poplar	1782	Idem.
Larch	from 970 to 1700	Idem.
Memel fir....	from 540 to 840	Bevan.
Scotch fir....	562	Idem.

Cohesive Force of a Square Inch of different Woods pulled asunder in the direction of their Length.

Kind of Wood, and specific gravity.	Cohesion of a Square Inch in pounds.	Experimentalist.
Oak, English 7	19,800	Bevan.
Oak	17,300	Muschenbroek.
Ditto, dry English { from ..... to	12,000 } 8,889 }	Barlow.
Beech ..... .72	22,000	Bevan.
Do.	17,709	Muschenbroek.
Do.	11,500	Barlow.
Alder	14,186	Muschenbroek.
Sycamore ..... .69	13,000	Bevan.
Chesnut, Spanish	13,300	Rondelet.
Do. ..... .61	10,500	Bevan.
Ash .. { from ..... to	17,850 } 15,784 }	Barlow.
Do.	12,000	Muschenbroek.
Elm ..... .69	14,400	Bevan.
Do.	13,489	Muschenbroek.
Mahogany ..... .87	21,800	Bevan.
Do.	8,000	Barlow.
Walnut	8,130	Muschenbroek.
Do. ..... .59	7,800	Bevan.
Teak	15,000	Barlow.
Do. old ..... .53	8,200	Bevan
Poplar ..... .36	7,200	Bevan.
Do. { from ..... to	6,641 } 4,596 }	Muschenbroek.
Norway Pine ..... .66	14,300	Bevan.
Petersburg Do. ..... .49	13,300	Bevan.
Fir { from ..... to	13,448 } 11,000 }	Barlow.
Do.	8,506	Muschenbroek.
Pitch Pine	7,818	Muschenbroek.
Norway Pine	7,287	Rondelet.
Larch	10,220	Rondelet.
Do. ..... .57	8,900	Bevan.

Table showing the Modulus of Elasticity of Beams pressed in the direction of their Length.

Kind of Wood.	Modulus of Elasticity in pounds.
English Oak	1,714,500
Beech	1,316,000
Alder	1,086,750
Chesnut, green	924,570
Ash	1,525,500
Elm	1,343,000
Acacia	1,687,500
Mahogany, Spanish	1,255,500
Do. Honduras...	1,593,000
Teak	2,167,074
Cedar, Lebanon	486,000
Riga Fir	1,687,500
Memel Fir	1,957,750
Norway Spruce Fir	1,804,000
Weymouth Pine	1,633,500
Larch	1,363,500

Result of Experiments by George Rennie, Esq.

Base 1 inch square, length 1 inch of Elm was crushed by 1,284 pounds
" " American Pine " 1,606 "
" " White Deal " 1,928 "
" " English Oak " 3,860 "
" length 4 inches Do. " 5,147 "
3 inches " " 6 to 9 in. African Oak " 60,480 "
= 6,720 pounds per square inch.*

* This is the mean of two experiments made by Mr A. H. Renton, with Bramah's press.

Experiments on the Strength of Woods supported at both ends.

KIND OF WOOD.	Specific gravity.	Length in feet.	Breadth in inches.	Depth in inches.	Deflection at the time of fracture in inches.	Weight that broke the piece, in pounds.	Authorities.
Oak, English, young tree.	.863	2	1	1	1.87	482	Tredgold.
Do., medium quality	.748	2.5	1	1		284	Ebbels.
Do., green	.763	2.5	1	1		219	Ebbels.
Beech, medium quality ..	.690	2.5	1	1		271	Ebbels.
Alder	.555	2.5	1	1		212	Ebbels.
Plane tree	.648	2.5	1	1		243	Ebbels.
Chesnut, green	.875	2.5	1	1		180	Ebbels.
Ash	.753	2.5	1	1	2.38	314	Tredgold.
Elm, common	.544	2.5	1	1		216	Ebbels.
Mahogany, Spanish, seasoned	.853	2.5	1	1		170	Tredgold.
Do. Honduras, seasoned	.560	2.5	1	1		255	Tredgold
Walnut, green	.920	2.5	1	1		195	Ebbels.
Poplar, Lombardy	374	2.5	1	1		131	Ebbels.
Teak	.744	7	2	2	4.00	820	Barlow.
Willow	.405	2.5	1	1	3	146	Tredgold.
Birch	.720	2.5	1	1		207	Ebbels.
Riga Fir	.480	2.5	1	1	1. 3	212	Tredgold.
Memel Fir	.553	2.5	1	1	1.15	218	Tredgold.
Norway Fir, from Long Sound	.639	2	1	1	1.125	396	Tredgold.
Scotch Fir, English growth	.529	2.5	1	1	1.75	233	Tredgold.
Christiana White Deal...	.512	2	1	1	937	343	Tredgold.
Spruce Fir, British growth	.555	2.5	1	1		186	Ebbels.
Larch, medium quality ..	.622	2.5	1	1		223	Tredgold.
Red Pine	. 54	4	3	3		3780	Fincham.
Yellow Pine	.439	4	3	3		2756	Fincham.

Experiments on the Strength of Beams supported at one end.

KIND OF WOOD.	Specific gravity.	Length in feet.	Breadth in inches.	Depth in inches.	Deflection at the time of fracture, in inches.	Weight that broke the piece, in pounds.	Experimentalist.
English Oak	.922	4	2	2		266	Beaufoy.
Dantzic Oak	.854	4	2	2		196	Idem.
Beech	.700	3	2	2	11	401	Barlow.
Ash	.730	2	1	2	6	321	Idem.
Teak, old, dry	.606	5	2	2	12½	257	Idem.
Virginian Yellow Pine ...	.522	5	2	2	11⅝	147	Peake and Barralier.
Canadian White Pine	.618	5	2	2	18⅜	122	Idem.
Pitch Pine		4	2	2		270	Beaufoy.
Larch, dry	.526	5	2	2	16¼	162	Peake and Barralier.
Red Pine	.544	2	3	3		1630	Idem.
Riga Fir	.537	4	2	2		210	Beaufoy.

The following remarks respecting the strength of cast and wrought iron, with the various Tables of Experiments, are extracted principally from the elaborate work on Tubular Bridges, by Mr. Edwin Clark, to which we would refer the reader for much valuable information on this subject. A further list, showing the strength of various materials in general use, will be found useful; it is obtained from the same source.

Mr. Telford commenced his experiments upon iron by proving what force would pull asunder, lengthwise, pieces of iron from $1\frac{1}{2}$ inches to $\frac{1}{20}$th of an inch in diameter. The experiments were made upon those of the largest diameter, by means of an excellent hydrostatic machine, and in those of the smaller by attaching weights perpendicularly, and repeating them at various times.

He then made several experiments upon different diameters, from $\frac{1}{10}$th to $\frac{1}{20}$th of an inch drawn horizontally, and with different degrees of curvature; and this was performed between points 900, 225, 140, and 139 feet 6 inches apart, and was repeated 200 times. In the experiments made upon $\frac{1}{10}$th of an inch and under, the wire was drawn over pulleys; sometimes both ends were fixed, and sometimes one end only, the other having weights attached perpendicularly, to show the effects when compared with those loaded upon the curved part of the wire; these last were disposed at $\frac{1}{4}$, $\frac{1}{2}$ and $\frac{3}{4}$ divisions of the distance over which it was stretched. These experiments being completed, it was ascertained what blow would break the wire when stretched nearly horizontally and at different curvatures, which was done by dropping weights from a given height. The several wires were weighed, and the weight of 100 in length of each noted.

The result of the experiments was, that a bar of good malleable charcoal iron, 1 inch square, will suspend 27 tons, and that an iron wire, $\frac{1}{10}$th of an inch in diameter, 200 feet in length, weighing 3 pounds 3 ounces, will suspend 700 pounds; and that the latter, with a curvature or versed sine of $\frac{1}{50}$th part of the chord line, will support $\frac{1}{10}$th of the weight suspended perpendicularly, when disposed equally at $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$, its length, and with a curvature of $\frac{1}{20}$th of the chord, it will bear $\frac{1}{3}$ of the aforesaid perpendicular weight disposed in a similar way. A wire, $\frac{1}{10}$th of an inch in diameter, drawn very tight between points, 31 ft. 6 in. apart, resisted the impulse of 20 pounds weight, falling from a height of 7 ft. 9 in.

A bar of good English malleable iron, 1 inch square, will suspend from 27 to 30 tons before it breaks, and will bear from 15 to 16 tons before its length is at all extended. With a curvature of $\frac{1}{20}$th of the length, malleable iron, besides its own weight, sustained $\frac{1}{3}$ of what broke it perpendicularly. An inch bar would therefore bear $\frac{1}{3}$ of 15 tons without deranging its parts; but it is better in practice to assume that an inch square in action should only bear 4 tons.

Table showing the Cohesive Force of Iron.

Kind of Iron.	Cohesion of square inch in pounds.	Experimentalist.
Iron Wire	93,964	Telford.
Swedish Iron	72,064	Rennie.
Do.	64,960	Telford.
English Iron	61,600	Telford.
Do.	56,000	Barlow.
Cast Iron, specific gravity, 7.716	32,700	Bevan.
Do.	19,488	Rennie.

Table showing the Extension, by a suspended Weight, of a Wrought-iron Bar, 10 feet long and 1 inch square.

Tons.	Observed extension in terms of the length.	Computed extension assumed uniform at $\frac{8}{100000}$ of the length per ton per square inch.	Corresponding extension in fractions of the length computed at $\frac{8}{100000}$ per ton per square inch.	Observed permanent set in terms of the length.	Observed permanent set in fractional parts of the length.
1	.000689	.0008	$\frac{1}{12500}$		
2	.000156	.00016	$\frac{1}{6250}$		
3	.000238	.00024	$\frac{1}{4150}$	.00000513	$\frac{1}{468750}$
4	.000319	.00032	$\frac{1}{3125}$	.00000283	$\frac{1}{350877}$
5	.000399	.00040	$\frac{1}{2500}$	.00000356	$\frac{1}{281030}$
6	.00048	.00048	$\frac{1}{2083}$	.00000427	$\frac{1}{233918}$

Table showing the Extension and Permanent Set of a Cast-iron Rod, 10 feet long and 1 inch square, drawn in the direction of its Length.

Tons.	Extension per Ton.	Total Extension.	Total permanent Set.
1	.01976	.01976	.00579
2	.02027	.04155	.001860
3	.02171	.06515	.003954
4	.02318	.09274	.007543
5	.02479	.12397	.012619
6	.02727	.16363	.020571

Table showing the Extensions of Cast-iron Rods, 10 feet long and 1 inch square, deduced from numerous Experiments, and compared with observed Compression of Bars of the same Irons and the same size, cast with them for comparison.

Extension.				Compression.				
	Weights laid on, with the corresponding Extensions, and Sets in Inches.					Mean Weights laid on, with corresponding Mean Compressions. Sets and Ratios of Weights to Compression.		
Number of Experiments.	Weights. (w)	Extensions. (e)	Sets.	(w) (e)	Number of Experiments.	Weights. (w)	Compressions in Inches. (d)	Sets in Inches.	(w) (d)
9	1053.77	.0090	...	117086	8	2064.745	.01875	.00047	110120
9	1580.65	.0137	.00022	115131	8	4129.49	.03878	.00226	106485
9	2107.54	.0186	.000545	113309	8	6194.24	.05978	.00400	103617
9	3161.31	.0287	.00107	110150	8	8258.98	.07879	.00645	104823
9	4215.08	.0391	.00175	107803	8	10323.73	.09944	.00847	103819
9	5268.85	.0500	.00265	105377	8	12388.48	.12030	.010875	102980
9	6222.62	.0613	.00372	103142	8	14453.22	.14163	.01405	102049
9	7376.39	.0734	.00517	100496	8	16517.97	.16338	.01712	101102
9	8430.16	.0859	.00664	98139	8	18582.71	.18505	.02051	100420
9	9483.94	.0995	.00844	95316	8	20647.46	.20624	.02484	100114
9	10537.71	.1136	.01062	92762	8	24776.95	.24961	.03220	99263
9	11591.48	.1283	.01306	90347	8	28906.45	.29699	.04300	97331
9	12645.25	.1448	.01609	87329	7	33030 80	.35341	.06096	93463
6	13699.83	.1668	.02097	82133	7	37159.65	.41149	.08421	....
4	14793.10	.1859	.02410	79576	..	....	....	....	...

Table showing the Compression of a Cast-iron Bar, 10 *feet long, and* 1 *inch Square.*

Tons.	Compression per Ton.	Total Compression.	Total permanent Set.
	Inch.	Inch.	Inch.
1	.020338	.020338	.000510
2	.021038	.042077	.002452
3	.021618	.064855	.004340
4	.021369	.085479	.006998
5	.021594	.107872	.009188
6	.021752	.130513	.011798
7	.021950	.153654	.015243
8	.022154	.177235	.018572
9	.022374	.201373	.024254
10	.022477	.224774	.028126
11	.022567	.248237	.032023
12	.022802	.273632	.037653
13	.023014	.299187	.043318
14	.023523	.329330	.052640
15	.023539	.353092	.060905
16	.024409	.390558	.080256
17	.024805	.421695	.086298

Table showing the Compression of Wrought and Cast-iron Bars, 10 *feet long, and* 1 *inch square nearly. The Experiments made by Mr. Hodgkinson.*

Cast-iron Bar. Area of Section 1.031 × 1.029.		Wrought-iron Bar. Area of Section 1.025 × 1.025.	
Weight laid on the Bar.	Decrease of length by that Weight.	Decrease of length of the Bar.	Weight producing that Decrease.
lbs.	Inch.	Inch.	lbs.
5054	.054	.052	9578
7316	.078	.073	14058
11818	.126	.130	25258
14058	.157	.154	29738
20778	.173	.174	31978
21898	.210	.214	34218

Table showing the Average Breaking-Weight of Bars 1 *inch square, and* 3 *feet long, as determined from a very extensive series of experiments by Mr. Robert Stephenson.*

Iron.	Ultimate Deflection.	Breaking Weight.
Hot blast	.789	826
Cold blast.....	.784	855
Mixtures of various Irons..	...	898

General Observations.

The tenacity of good Baltic fir is very remarkable; sound rods of this material will bear an ultimate tensile strain of 5 tons per square inch, the specific gravity of which being from $\frac{1}{2}$ to $\frac{3}{4}$ of that of water, so that it will be about $\frac{1}{2}$ or $\frac{3}{4}$ immersed when floating in that liquid; the weight may be taken generally at about 45 lbs. per cubic foot, or nearly one-tenth that of wrought-iron, while the ultimate strength amounts to one-fourth. Thus a tension-rod of wrought-iron will be $2\frac{1}{2}$ times as heavy as a tension-rod of Baltic fir of the same strength, and of four times the sectional area.

Its elasticity is about one-fifteenth that of wrought-iron; i. e. a bar one inch square is extended on $\frac{1}{150000}$th of its length per ton of direct tensile strain.

The difficulty of connecting timber longitudinally, is a complete bar to the use of deal in cases of tensile strain, in greater lengths than it is naturally produced; the balks imported vary from 40 to 60 and 70 feet in length, being from 12 to 16 inches square.

In practice, wrought-iron should not be strained beyond 10 tons per square inch, and deal $2\frac{1}{2}$ tons per square inch.

An ordinary round rod of wrought-iron, 1 inch in diameter, bears tensilely 16 tons, and weighs 8 lbs per yard.

For a round rod of any diameter, the square of the diameter, taken in greater inches, is the breaking weight in tons.

Half this quantity is the weight in lbs per yard. Thus the breaking weight of a round bar 5 inches, or 20 quarter-inches in diameter, will be 20 × 20 or 400 tons, and the actual weight will be half 400 or 200 lbs. per yard.

A rod will be perceptibly damaged by half this strain, which can never be safely exceeded, one-third being sufficient in practice.

The strength of chain-cable is thus easily arrived at, the strength of a link being double that of the bar from which it is forged.

It is usual technically to denominate chains by their diameter, thus a five-eighth chain is a chain made from a bar $\frac{5}{8}$ inch in diameter.

The following approximations will be found very convenient in estimating the weight and strength of chains, the ultimate tensile strength of the material being taken at 16 tons per circular inch, or 20 tons per square inch of section.

1. The square of the diameter in eights, will be the weight of the chains in lbs. per fathom.

2. The square of the diameter in eights, divided by 2, will be the breaking weight in tons. Thus the breaking-weight of a $\frac{5}{8}$ chain will be half 25 tons = $12\frac{1}{2}$ tons, and the actual weight will be 25 lbs. per fathom of 6 feet.

N. B.—A chain will be perceptibly damaged by half this strain, which can never be safely exceeded, one-third being sufficient in practice.

The strength of ropes is very uncertain, their size is generally denominated technically by their circumference in inches; and the following approximations will be very correct for ordinary tarred hempen rope:—

1. The square of the circumference in inches, divided by 10, will give the practical strength in tons, which will be about half their breaking-weight.

2 The square of the circumference, divided by 4, will roughly give the weight in lbs. per fathom. Thus the useful strength of a 5-inch rope will be $\frac{25}{10}$ or 2.5 tons, the ultimate strength being 5 tons; and the weight of a tarred 5-inch rope will be $\frac{25}{4}$ or $6\frac{1}{4}$ lbs. per fathom.

A rope of 10 inches in circumference, and a chain of $\frac{6}{8}$-3ths diameter, will each bear practically about 10 tons, taking half the breaking-weight, and the weight of the former will be 25 lbs., and of the latter, $39\frac{1}{2}$ lbs. per fathom.

Transverse Strength of a Slab of State from the Penrhyn Quarries.

A slab of slate 2 feet 10 inches broad, 4 inches thick, and 4 feet between the bearings, failed with $24\frac{1}{2}$ tons distributed over 15 inches at the centre of the span.

A slab of cast-iron of the same dimensions would scarcely support five times as much, and would be above two and a half times as heavy. This material forms a valuable flooring for bridges.

Transverse Strength of Timber.

To avoid any anomalies in deducing the strength of large beams of timber from experiments on small battens, the fol-

lowing experiments were made on the transverse strength of whole balks of American red pine timber selected from the scaffolding employed in erecting the tubes.

These beams were exactly 12 inches square and 17 feet long, the distance between the bearings being 15 feet. They were broken by actual weight suspended on a scale from the centre of the beams.

Dry timber from the butt end of the balk:—

Weight of the beam, 5 cwt. 2 qrs. 5 lbs. or 36.5lbs. per cubic foot.

Breaking weight, 14.82 tons.

Dry timber from the top of the balk:—

Weight of the beam, 5 cwt. 17lbs. or 33.9lbs. per cubic foot.

Breaking weight, 13.24 tons.

Results of Experiments made with actual Weight on Materials used in the Britannia Bridge, January, 1848.

(*Brickwork.*)

lbs. per sq. in.

No. 1. 9-inch cube of cemented brickwork (Nowell and Co.,) No. 1 (or best quality), weighing 54 lbs., set between deal boards. Crushed with 19 tons 18 cwt. 2 qrs. 22 lbs. . . . = 551.3

No. 2. 9-inch brickwork, No. 1 weighing 53 lbs., set in cement. Crushed with 22 tons 3 cwt. 17 lbs. . . . . = 612.7

No. 3. 9-inch brickwork, No. 3 weighing 52 lbs., set in cement. Crushed with 16 tons 8 cwt. 2 qrs. 8 lbs. . . . . = 454.3

No. 4. 9¼-inch brickwork, No. 4 weighing 55½ lbs., set in cement. Crushed with 21 tons 14 cwt. 1 qr. 17 lbs. . . . . = 568.5

No. 5. 9-inch brickwork, No. 4 weighing 54½ lbs., set between boards. Crushed with 15 tons 2 cwt. 12 lbs. . . . . = 417.

Mean . . . . . 521.

Note.—The three last cubes of common brick continued to support the weight although cracked in all directions; they fell to pieces when the load was removed. All the brickwork began to show irregular cracks a considerable time before it gave way.

The average weight supported by these bricks was 33.5 tons per square foot, equal to a column 583.69 feet high of such brickwork.

(*Sandstone.*)

No. 6. 3-inch cube red sandstone, weighing 1 lb. 14⅜ oz., set between boards (made quite dry by being kept in an inhabited room). Crushed with 8 tons 4 cwt. 19 lbs. . . . . = 2043.

No. 7. 3-inch sandstone, weighing 1 lb. 14 oz., set in cement (moderately damp). Crushed with 5 tons 3 cwt. 1 qr. 1 lb. . . . . = 128.5

No. 8. 3-inch sandstone, weighing 1 lb. 15½ oz., set in cement (made very wet). Crushed with 4 tons 7 cwt. 21 lbs. . . . . = 1085.

No. 9. 6-inch cube sandstone, weighing 18 lbs., set in cement. Crushed with 63 tons 1 cwt. 2 qrs. 6 lbs. . . . . = 3924.8

No. 10. 9¼-inch cube sandstone, weighing 58½ lbs., set in cement (77½ tons were placed upon this without effect = 2042 lbs. per inch, which was as much as the machine would carry).

Average crushing weight . . . . 2185.

All the sandstones gave way suddenly, and without any previous cracking or warning. The 3-inch cubes appeared of ordinary description; the 6-inch was fine-grained, and apparently tough, and of superior quality. After fracture, the upper portion generally retained the form of an inverted square pyramid about 2½″ high, and very symmetrical, the sides bulging away in pieces all round. The average weight of this material was 130 lbs. 10 oz. per cubic foot, or 17 feet per ton.

The average weight required to crush this sandstone is 134 tons per square foot, equal to a column 2351 feet high of such sandstone.

(*Limestone.*)

lbs. per sq. in.

No. 11. 3-inch cube Anglesey limestone, weighing 2 lbs. 10 oz., set between boards. Crushed with 26 tons 11 cwt. 3 qrs. 9 lbs. . . . . = 6618.

This stone formed numerous cracks and splinters all round, and was considerably crushed; but, upon removing the weight, about two-thirds of its area were found uninjured.

No. 12. 3-inch limestone, weighing 2 lbs. 9 oz., set between deal boards. Crushed with 32 tons 6 cwt. 1 lb. . . . . = 8039.

This stone also began to crack and splinter externally with 25 tons (or 6220 per inch), but ultimately bore as above.

No. 13. 3-inch limestone, weighing 2 lbs. 9 oz., set in deal boards. Crushed with 30 tons 18 cwt. 3 qrs. 24 lbs. . . . . = 7702.6

No. 14. 3 separate inch cube limestone, arranged in a triangle, weighing 4½ oz., set between deal boards. Crushed with 9 tons 7 cwt. 1 qr. 14 lbs. . . . . = 6995.3

All crushed simultaneously.

Average . . . . . 7579.

7338.5

All the limestones formed perpendicular cracks and splinters a considerable time before they crushed. Weight of the material from above = 165 lbs. 5 oz. per cubic foot, or 13½ feet per ton.

The weight required to crush this limestone is 471.15 tons per square foot, equal to a column 6433 feet high of such material.

(*Single Bricks of different qualities.*)

No. 15. A single brick, No. 1 (Nowell and Co.), weighing 8 lbs., bedded flat in cement. Crushed with 17 tons 19 cwt. 1 qr. 7 lbs. . = 1022.

No. 16. A single brick, No. 3. Crushed with 13 tons 11 cwt. 1 qr. 6 lbs. . . . . = 750.

No. 17. A single Birkenhead brick, 9 × 4½″, weighing 7 lbs. 14 oz., bedded in cement. Crushed with 32 tons 2 cwt. 17 lbs. . . . = 1775.8

No. 18. A single Buckley mountain brick, 9½″ × 4½″, weighing 9 lbs. 2 oz., bedded in cement. Crushed with 40 tons 13 cwt. 15 lbs. = 2130.3

These last experiments not being on cubes, only serve for comparisons among themselves. The bricks were completely crushed into powder. The cement used in all the above experiments invariably began to crack away round the edges as soon as a very moderate weight was applied.

STRETCHED OUT, a term applied to a surface that will just cover a body, and is extended in such a manner that all its parts are in a plane, or may be made to coincide with a plane.

STRETCHER, a term applied to bricks or stones so placed in a wall that their longest side shall be parallel to the face of the wall; those bricks, on the contrary, which have

their longest dimension in the heart of the work, perpendicular to the surface, are termed *headers* or *through-bricks*.

STRETCHING COURSE, in walling, a course of stones, or bricks, laid with their longest dimensions in a horizontal line parallel to the face of the wall: it is exactly the contrary of *a heading course*, where the breadths of the stones, or bricks, are laid in a straight line parallel to the face of the wall.

STRIÆ (Latin), the fillets or rays which separate the furrows, or grooves, of fluted columns.

STRIGES (from the Latin *striga*, a ridge), the channels of a fluted column.

STRIKING, Sticking, or Running a Moulding, in joinery, is the shaving away the superfluous part of the wood, till the section be of the required figure.

Striking is also applied to the drawing of lines by the square on the face of a piece of stuff for mortises, and cutting the shoulders of tenons, &c.

Striking is also used for the drawing of lines on the surface of a body.

Striking a Centre, the removal of the centre after the completion of the arch it had supported during the building, and during the time necessary for the mortar to consolidate.

STRING-BOARD, in wooden stairs, a board placed next to the well-hole, and terminating the ends of the steps. The face of string-boards follows the direction of the well-hole, whether it be prismatic or an inverted cone. String-boards are sometimes glued in several thicknesses, with the fibres of the wood running in the direction of the steps; sometimes they are wrought out of the solid, like a hand-rail, the grain of the wood being in the same direction; and they are sometimes also glued up like columns, viz., having the fibres vertical. Brackets are most frequently placed upon the string-boards, and mitred into the risers.

String-Course, a narrow continuous horizontal moulding or plat-band, projecting slightly from the face of the wall.

String-Piece, the piece, or pieces, of timber, put under the flying steps of a wooden stair, for their support, and covered with the lath and plaster forming the soffit of the stair.

STRIX, (Latin,) a channel in a fluted column.

STRUCK, an architectural expression, when anything of a temporary kind is taken away, which had been used for the support of some part of the building during its erection; as the centre of a vault, &c. *See* Striking.

STRUTS, in a truss, are one or more pair of oblique straining-pieces, each pair tending and pressing to a point below either of their extremities, and making equal angles with the horizon, though in contrary directions. Every strut is a brace; but every brace is not a strut. Braces may meet on either side of their extremities, above or below them; but struts only meet or tend to the same point downwards, as already defined.

Struts occur most frequently in roofs, and braces in partitions. Braces, when they occur in roofs, are called *principal braces, auxiliary rafters, cushion rafters*, or *discharging braces:* when they occur in the same frame, they are used in opposition to each other; though it would be as well to have a separate term to express the idea of braces when they meet upwards, as, in this way, there could be no ambiguity of expression.

STRUTTING BEAM, or Strut Beam, a term used by old writers in carpentry, for what is now called *straining beam*, or *collar beam*.

Strutting Piece. *See* Straining Piece.

STUCCO, (from the French, *estoc.*) *See* Cement, Mortar, and Plastering.

STUDS, (from the Saxon *studer*, a post,) the posts, or quarters, in partitions, placed eleven or twelve inches distant; the term is frequently used in London and in Somersetshire. The studs go also under the various names of *uprights* and *quarters*, in London.

Stud Partitions, the same as quarter partitions.

Stud Work, or Brick-Nogging, a wall consisting of brick-work, built between studs, or quarters, chiefly used in thin walls, or partitions, for greater strength than when bricks are used without studs. *See* Brick-Nogging.

Stuff, (from the Dutch, *stofe*,) a general term for the wood upon which joiners work.

STYLE, or Stile, the upright supports of a frame.

STYLOBATE, the substructure of a classic temple below the base of the columns, or the platform on which the building was elevated. This consisted either of a series of steps continued all round the temple, or of a podium or wall, which admitted of access to the temple at one end only.

SUB-BASE, a second base below the first or true base.

SUBNORMAL, or Superpendicular, the distance upon the axis between the foot of the ordinate and a perpendicular to the curve, or its tangent.

In all curves, the subnormal is a third proportional to the subtangent and the ordinate; and in the parabola it is a constant quantity, being equal to half the parameter of the axis.

SUB-PLINTH, a plinth below the true plinth, and on which the latter stands.

Sub-Principals, the same as auxiliary rafters, or principal braces.

SUMMER, a large stone, the first that is laid over columns and pilasters, in beginning to make a cross vault; or that stone, which being laid over a piedroit, or column, is made hollow, to receive the first haunce of a platband.

Summer, a large piece of timber, which being supported by two stone piers, or posts, serves as a lintel to a door, window, &c.

Summer, a beam of timber tenoned into a girder, for supporting the ends of joists on both sides of it. The distinction of the large beams of a carcase floor is, that *bressummers* are disposed in exterior walls; *girders* lie across the building; and the *summers* divide the floor in the middle, and are laid perpendicular to girders, or parallel to the bressummers.—Summers are now seldom or never employed in building.

Summer is also a Warwickshire term for a girder.

Summer-House, a house situate in a garden, or on some pleasant sequestered spot, on an estate, for the purpose of retiring to in the summer.

Summer-Tree, a beam full of mortises for the ends of joists to lie in, and to which the girders are framed. *See* Bressummer and Girders.

SUNK SHELVES, have a groove consisting of two sides, to prevent the plates from sliding off, when set up on edge.

SUPERCILIUM, in ancient architecture, the uppermost member of the cornice, called by the moderns, *corona*, *crown*, or *larmier*. It is also used for a square member under the upper torus, in some pedestals.

SUPERSTRUCT, (Latin,) to build one thing upon another.

SUPERSTRUCTURE, the upper portion of a building raised upon the foundations.

SUPPORTERS, images to bear up, or serve instead of posts, &c., in a building. The posts themselves are sometimes so called.

SURBASE, the mouldings of a room, immediately above the base, with the dado between.

SURMOUNTED ARCH, that which has its springing line below the level of the centre from which it is struck.

SURVEYING, the practice of measuring the areas and defining the boundaries of plots of land, estates, houses, &c., in such a manner as to be able to transfer a correct representation of the same to a plan showing the relative position and proportionate dimensions of the various parts with reference to each other. In other words, the plan is made to present, on a small scale, a delineation of the surface of the area surveyed.

The principal instruments employed in surveying are the theodolite and chain; the former for measuring angles, and the latter for lines. It is usual to divide the plot to be surveyed into a number of triangles, as convenient, and, when the chain only is used, which is probably the more accurate method, to measure the three sides of each triangle, which at once determines its form and dimensions. If, however, the theodolite be also used, one or more of the angles are measured thereby, and one or more sides determined by the chain; in this case, the form and dimensions of each triangle may be determined by trigonometrical formulæ. In surveying large tracts of country, it is usual to fix or determine the relative position of some of the more conspicuous points by a system of triangulation, and from these fixed points, as a basis, to determine or fill in the remainder of the plan. Several other instruments are employed in these operations, but the two above-mentioned are the principal.

Surveying Wheel. *See* Perambulator.

SUSPENSION BRIDGE. This kind of construction is, perhaps, the simplest and most easily erected of all bridges; we find examples of it spoken of in remote times, and there are few countries in the world where it may not be seen under some form or other. In England we now have many splendid bridges of this description, in which the combined labours of practical experimentalists and scientific theorists have produced monuments of surprising skill and admirable daring.

The principle on which suspension bridges are constructed, is exactly the reverse of that on which the stability of arched bridges depend. In the latter case, the force of gravity is, by an ingenious arrangement, made to counteract the natural tendency of all bodies to fall towards the earth; and a *compressive* force is called into play, by which the several parts of the bridge are kept in their proper positions, provided the materials have been properly disposed, and are sufficiently strong to bear the requisite crushing force.

In suspension bridges, on the contrary, the roadway is supported by ropes or chains attached to towers and abutments, so that the *tension* of the materials employed is *principally*, although not altogether, acted upon, and the platform is sustained by the excess of their tensile powers above the weight (their own included) with which they are loaded. These bridges were not constructed to any great extent until the commencement of the present century; up to that period they were of rather a primitive character. We hear, indeed, of one built in China about the year 65 A.D., and of several suspended bridges in South America and the Indies, in which the chains were formed of ropes or barks of trees plaited or interwoven together, so that the roadway was in the form of a catenary curve; still, even in those countries we have instances of the roadway or platform being placed horizontally, and suspended from the ropes or chains by intermediate rods. Among the first Iron Suspension bridges put up in this country was the Winch Bridge crossing the river Tees near Middleton. It was merely intended for foot-passengers, being only 2 feet in width, although 70 feet long. In 1816, a Wire Suspension bridge was built over the Gala Water, of upwards of 100 feet span, at a cost of only £40; and another over the Tweed at Peebles in the following year, also of iron wire, and about the same span, for £160.

In 1820, Captain Sir Samuel Brown built a Suspension Bridge over the Tweed, in an ingenious and novel manner, for which he had obtained a patent in 1817. Instead of making the main iron chains, intended for the support of the bridge, in the form of ropes, as had been hitherto done, he constructed those chains by links of iron several feet in length, with holes formed at either end, through which he joined them together by means of bolts. This bridge, called the Union, is situate close to Berwick-on-Tweed, and has a span of 449 feet. It is supported upon 12 chains disposed in pairs, and placed one above the other 3 deep, formed by links of round iron 2 inches in diameter, and each 15 feet long, connected with one another by intermediate short links also of iron. The suspending rods are of an oval section, and are placed 5 feet apart, every one being attached to a joint of one of the three main chains, which are made to break joint, so as to admit of this arrangement. These suspension rods support the roadway, which is formed of timber. This bridge cost £50,000. In the following year, this engineer built the Newhaven Pier, which is constructed on the same principle, having three openings, each 209 feet span; and afterwards the Chain Pier at Brighton, which runs out into the sea a distance of upwards of 1,000 feet, having four openings, each 225 feet span. In the year 1823, a bridge of the kind was erected by Sir Isambert Brunel, with two spans, each 122 feet; and the year after (1824) Tierny Clarke constructed the much-admired Suspension Bridge over the Thames at Hammersmith, spanning the river by an opening of 422 feet, which has stood remarkably well.

Next in order of time is the far-famed Suspension Bridge erected by Telford over the Menai straits, for the purpose of carrying the Holyhead road, and thus connecting the Island of Anglesea with the mainland. This splendid work of art was completed in the year 1825, having been about six years in course of construction. It consists of one opening of 570 feet span. The roadway being 100 feet above the level of high-water. The chains are formed of flat bars of iron 10 feet long, $3\frac{1}{2}$ inches deep, and nearly an inch thick. There are four rows of chains, each consisting of four tiers of bars ranged one above the other, so that, in all, there are 16 chains; to these, which are passed over the tops of two lofty towers placed at either side of the straits, and fastened at either shore into the solid rock, bars an inch square are attached, 5 feet apart, for the purpose of supporting the roadway, which has two carriage-ways, each 12 feet wide, and a central footway 4 feet in width. The entire weight of this suspended platform, including the 16 chains, is about 2,186 tons. The Conway bridge, over the river Dee, is also a Suspension Bridge, and was built by Telford about the same time; it has a span of 327 feet, and likewise carries the great Holyhead road. Sir Samuel Brown then erected, in the year 1829, the Montrose Suspension Bridge over the Esk in Scotland, with a span of 412 feet, and a roadway 12 feet wide. This bridge was all but destroyed during a great storm which took place in 1838; the platform not having sufficient rigidity to withstand the unequal force of the wind. The engineer, Rendel, however, has restored the bridge, and it is thought that such a disaster cannot again take place.

In the year 1829, M. Navier, an able French engineer, to whom we are indebted for a valuable work on Suspension Bridges, constructed the Pont des Invalides, on the suspension principle, over the Seine at Paris, with a span of 236 feet, and a deflection in the catenary formed by its chains, of about 26 feet. The Fribourg Bridge, which spans the valley of the Sarine in Switzerland, is one of the most splendid wire bridges ever built. It was constructed by Mr. Challey between the years 1832 and 34. It has a span of 870 feet, and

the platform is 167 feet above the surface of the water, which runs at the bottom of the valley. This platform is suspended from four iron-wire ropes, two on each side of the bridge. The ropes are composed of 80 wires, each $\frac{1}{12}$ of an inch diameter, tied up by coils of wire at regular intervals; these chain-ropes are made fast to the rock on either side, after passing over the tops of the towers. Suspension rods are then hung upon the chain-ropes, to which the joists forming the roadway are fixed; the cost of this magnificent and truly wonderful structure did not amount to more than £24,000.

SWALLOW-TAIL, a particular way of fastening together two pieces of timber, so strongly, that they cannot fall asunder. It is much the same as Dove-tail.

SWELLED COLUMN. *See* Column.

SYMBOLICAL COLUMN. *See* Column.

SYMMETRY, (from the Greek, συν, *with*, and μετρεω, *to measure*,) the harmony, proportion, or uniformity between the parts of a building and the whole.

SYSTYLE, a building where the pillars stand thick, but not quite so thick as in the pycnostyle, the intercolumniation being only two diameters, or four modules of the columns.

T.

TAI

TABERN, a local word for cellar.

TABERNACLE, a casket composed of marble, precious stones, or metal, placed upon the altar in churches, and employed to contain the consecrated wafer; also any casket for containing holy relics, vessels, &c. The term is further applied to decorated niches, with enriched canopies, &c.; a collection of such work is termed *Tabernacle-work*.

TABLE, or Tablet, a flat surface or panel of various forms, but usually rectangular, either plain, or charged with ornament of some kind. They are frequently made to project from the wall, and are termed *raised tables*.

The term is also applied to continuous horizontal mouldings; thus we have *bench*, *corbel*, *water tables*, *&c.*

Table Corbel, a curious horizontal ornament, used, in Gothic architecture, for a cornice.

Table, *Projecting*, as its name imports, is a table projecting from the naked of a wall.

Table, *Raised*, the same as Projecting Table.

Table, *Raking*, one that is not perpendicular to the horizon.

Table, *Rusticated*, a table of which the surface is rough, from being broken with the hammer, frosted, or vermiculated.

Table, *Water*, one that inclines to the horizon, for throwing off water; this kind is mostly used in buttresses, and other parts of Gothic edifices.

Table, in perspective, the same as *the plane of the picture*, being the paper or canvass on which a perspective drawing is made, usually perpendicular to the horizon. In the theory of perspective, it is supposed to be transparent, for the more easily comprehending the subject.

Table of Glass, in glass-works, and among glaziers, a circular plate of glass, being its original form, before it is cut, or divided into squares. Twenty-four tables make *a case*.

Tabled, a term applied to anything cut into tables.

TABLET, the same as Table.

TABLING, a term used in Scotland for the coping of the wall of very common houses; also a method of scarfing timbers.

TACKS, small nails, for fastening and stretching cloth upon a board, &c.

TÆNIA, or Tenia, a small square fillet at the top of the architrave, in the Doric capital.

TAIL, *Swallow*. *See* Swallow-tail.

Tail-in, to fasten anything into a wall at one end, as the steps of a stair; this expression is similar to what, in joinery, is called *housing*.

TAS

Tail Trimmer, a trimmer next to the wall, into which the ends of joists are fastened, in order to avoid flues.

TAILING, the part of a projecting stone, or brick, inserted in a wall.

TAILOIR, a term used by some writers, in imitation of the French, for the Abacus.

TALON, (French,) the same as Ogee; being either the cima-recta or cima-reversa: according to some authors, it is a kind of astragal, used as a crowning. The word is not used in England.

TALUS, or Talut, the slope or inclination of a wall, whereby, reclining at the top, so as to fall within its base, the thickness is gradually lessened according to the height. Among workmen, this is called *battering*; and the wall itself is said *to batter*; but when the wall inclines beyond the perpendicular of its base, it is called *hanging*. The term *talus* is mostly restricted to fortifications.

TAMBOUR, (a French term, derived from the Arabic, *tambor*, a drum,) a word applied to the naked of a Corinthian or Composite capital, or to that part from which the ornaments are supposed to project.

Tambour, is also applied to the wall of a circular temple, which is surrounded with columns.

Tambour, a place enclosed with folding-doors, to break the current of air from without, at the entrance of churches, or other similar buildings.

TANGENT, (Latin, *tangere*, to touch,) in geometry, a line or surface which touches another without cutting it. The term is more especially applied in trigonometry to the line drawn, touching the circumference at the commencement of the arc, and terminated by the secant, which is drawn through the centre and the end of the arc.

TANK, a large vessel, or reservoir, to contain water.

TAPERING, a term expressive of the nature of a solid contained between two opposite planes inclined towards each other. Thus, the wedge, the pyramid, the frustum of a pyramid, the cone, and the frustum of a cone, are all tapering solids.

TAPESTRY, hangings of wool, silk, and other materials, and ornamented with embroidery of various kinds of needle-work, employed as decorative coverings to the walls of ancient houses.

TARRACE. *See* Terrace.

TARRAS, or Terras, a strong mortar or plaster, of great use in aquatic works. *See* Cement, Mortar, and Plaster.

TASSELS, (from the French,) in common country houses, the pieces of timber that lie under the mantel-tree.

TAXIS, the same with the ancients that ORDONNANCE is with the moderns, and described by Vitruvius, as that which gives every part of a building its just dimensions, according to its uses.

TEAZE-TENON, a tenon upon the top of a post, with a double shoulder and tenon from each, for supporting two level pieces of timber at right angles to each other.

TEINT, (from the French,) a wash of any colour upon paper.

TELAMONES, the Roman term for the figures or images of men supporting a cornice or other projection. By the Greeks they were called ATLANTIDÆ, ATLASES, and PERSIANS.

TEMOIN, (from the French,) in fortification, a pillar, or mound of earth, left by the workmen in digging, to show how much has been removed, and what they are to have for their labour.

TEMONES, (from the Greek, τεμνος,) in ancient temples, the place where the image stood.

TEMPERED, a term applied to such bricks as are easily cut and reduced to a required shape.

TEMPLE, (from the Latin *templum*,) a building erected in honour of some deity, whereat the people met for religious worship. Clemens Alexandrinus and Eusebius refer the origin of temples to the sepulchres for the dead: Herodotus and Strabo will have the Egyptians to have been the first who raised temples to the gods: others say, that the portable temple, or tabernacle, made by Moses in the desert, was the first of the kind, and these hold it to have been the model of all others. The first temple erected in Greece is ascribed to Deucalion by Apollonius; as the first in Italy is said to have been built by Janus, or Faunus. In antiquity, we meet with many who would not build temples to their gods, for fear of confining them to too narrow bounds. They performed sacrifices and other religious rites in all places indifferently, from a persuasion, that the whole world is the temple of God, and that he requires no other. This was the doctrine of the Magi, followed by the Persians, Scythians, Numidians, and many other nations mentioned by Herodotus, Cicero, and Strabo. The Persians, who worshipped the sun, believed it would be injurious to his power to enclose within the walls of a temple him who had the whole world for his habitation; and hence, when Xerxes ravaged Greece, the Magi exhorted him to destroy all the temples he found. The Athenians would erect no temple to Clemency, who, they said, was to live within the hearts of men, not within stone walls. The Bithynians and Germans had no temples, but worshipped on mountains and in woods.

Temples were built and adorned with all possible splendour and magnificence; and this partly out of reverence for their respective deities, and partly to create an awe for them in those who came to pay their devotions. The temples were built after that manner which different votaries thought most agreeable to their Gods; for instance, the Doric pillars were sacred to Jupiter, Mars, and Hercules; the Ionic to Bacchus, Apollo, and Diana; and the Corinthian to Vesta; though there are instances of these being used in the same temples; such were some of those dedicated to Minerva, which had pillars of the Doric, Corinthian, and Ionic orders. Wherever a temple stood, if the situation of the place would permit, it was so contrived, that the windows, on being opened, might receive the rays of the rising sun. The front was towards the west, and the altars and statues were placed towards the other end, that the worshippers, on entering, might have their faces towards them, it being a custom among the heathens to worship with their faces towards the east. If the temples were built by the side of a river, they were to look towards the banks of it; if near the highway, they were to be so ordered, that travellers might have a fair prospect of them, and pay their devotions to the god as they passed: those built in the country were generally surrounded with groves. In the front of the temple was the porch, in which, according to Casaubon, was placed the holy water, in a vessel of stone or brass, with which all who were admitted to the sacrifices were sprinkled; beyond this porch it was not lawful for the profane or polluted to pass; this led into the body of the temple, where was the *adytum*, or sacred place, into which none entered but the priests. Belonging to each temple there was a vestry, which seems to have been a treasury both for the temple itself, and for such also as had a mind to secure their wealth in it, as was done by Xenophon, who committed his treasures to the custody of the priest of Diana, at Ephesus.

Temples are thus described by some of the ancients: first, the whole edifice; secondly, the altar on which the offerings were made; thirdly, the porch in which usually stood an altar, or an image; and lastly, the place upon which the image of the chief god was erected. This idol was originally only a rude stone; and Themistius tells us, that thus they all continued till the time of Dædalus, who first gave them feet. In after-ages, when the art of graving and carving was invented, those rude lumps were changed into figures resembling living creatures, generally men. The material of these statues, among the Greeks, was generally wood; and it has been observed, that those trees which were sacred to any particular deity, were thought most acceptable for his statues: thus, Jupiter's were made of oak; Venus', of myrtle; Minerva's, of olive; Hercules', of poplar, &c. Sometimes they were the work of the lapidary, and consisted of common or of precious stones; at other times of black stone, indicating the invincibility of the gods: marble and ivory were frequently made use of, sometimes clay and chalk; and, last of all, brass, silver, gold, and other metals. The place of the images was in the middle of the temple, where they stood on pedestals raised above the height of the altar, and enclosed with rails.

The most ordinary form given to temples was that of a long square; though sometimes they were of a circular form. Those which were of the former shape were generally twice as long as broad, and their cella had generally, on the exterior, porticos, which adorned sometimes only the front façade, sometimes both the front and back façade, and, at others, were carried all round the four sides. The enclosed part of the temple was called the *naas domos selias*, or *cella*. The front portico was termed *frons, pronaos, prodomos, anticum*: the back part, when it had an entrance and portico, was termed *posticum* and *opisthodomus*. Above the entablature of the two columns of the two façades was the *tympanum*, or *aetos*.

The façades of temples had always an even number of columns, either four, six, eight, or ten; and from these numbers they received the names of *tetrastyle, hexastyle, octostyle*, or *decastyle*. On the two sides the columns were generally an odd number. The Grecian and Roman architects, however, were not agreed as to the disposition of the columns on the sides. When the façade had six or eight columns, the Greeks placed on each side thirteen or seventeen. Examples of this are seen in the small temple at Pæstum, in the temples of Juno Lucinia, and of Concord, at Agrigentum, in that of Jupiter Nemæus between Argos and Corinth, in that of Theseus, and the Parthenon at Athens, and in several others. The Romans, on the contrary, reckoned by the intercolumniations, and, according to Vitruvius, they gave to each side twice the number of intercolumniations of the façade, so that a temple, which had six or eight columns in

front, would have on each side eleven or fifteen. Thus the temple near Mylassa had six columns on the façade, and eleven on each side; that of Fortuna Virilis, at Rome, had four in front, and seven on each side. Sometimes, however, the columns at the side are an even number, and either double, or not double, of those at the front. Thus the temple of Jupiter Panhellenius, in the island of Ægina, had six in front and twelve on each side. The temple of Ægesta in Sicily, as well as the grand temple at Pæstum, have six columns in front, and fourteen on each side. Some temples at Selinus have six columns in front, and on the sides of one of them twelve, one fourteen, and another sixteen. The greatest temple in this city had eight in front, and sixteen on each side.

Temples are classified by Vitruvius into seven different kinds, determined according to the disposition of the columns: viz., the temple *in antis*, *prostylos*, *amphiprostylos*, *peripteros*, *dipteros*, *pseudo-dipteros*, and *hypæthros*.

The temple *in antis* is the most simple in form, consisting only of the cella, with a portico formed by the projection of the side-walls beyond the end-walls of the cella, the ends of the projections being enriched with capital and base similar to a pilaster; between the antæ were two columns, one on either side of the entrance. These temples were devoid of columns on the flanks, and are termed *astylar*, or devoid of columns. The *prostyle* temple had columns only on its front or fore side. The *amphi-prostyle* had columns both before and behind, and was also tetrastyle. The *peripteral* or *peristylar* temple was surrounded on all sides by a colonnade, and, according to Vitruvius, had six columns in the front, and eleven in the flanks, including those at the angles; the space between the peristyle and walls of the cella was of the width of one intercolumniation. The number of columns in the flanks of Grecian hexastyle peripteral temples does not appear to have been regulated by the number in the fronts; it has been believed it always exceeded double that of those in the front; but in the temples of Ægina, Pæstum, Argos, Syracuse, Ægesta, and Selinus, it generally exceeds the double by two or more. Peristylar temples are of two kinds, those with a single row of columns on each side, and those which have two rows, and which are distinguished as *dipteral*. These were octostyle in the fronts, with fifteen columns in the flanks, the walls of the cella ranging with the columns at the ends which were third in order from the angles. The *pseudo-dipteral* differed from the dipteral only in omitting the innermost of the two ranges of columns which surrounded the cella. The peripteral, dipteral, and pseudo-dipteral temples all presented the same general appearance, but in the second some advantage was obtained over the first in the extended width of the fronts, but more especially in the variety of effect in shadow and perspective, and in the extension of sheltered space which was gained for ambulatories. In the third kind, the second advantage was lost, but the last was considerably increased by the clear space gained by the omission of the inner row of columns; in fact, this arrangement was similar to the first, with the exception that the space between the cella and the colonnade was twice as great.

The *hypæthral* temple was open at top, and exposed to the air. Of this latter description, some were decastyle, others pycnostyle; but they all had rows of columns within, forming a kind of peristyle, which was essential to this sort of temple. The last kind was the *monopteral* temple, which was round, and without walls, having its dome supported by columns. Sometimes, however, we find circular *astylar* temples.

TEMPLET, a mould used in masonry and brickwork, for the purpose of cutting or setting the work. When great nicety is required, two templets should be used, one for moulding the end of the work, and its reverse for trying the face. Where many stones or bricks are required to be done with the same mould, the templets ought to be made of copper.

Templet, a short piece of timber, sometimes laid under a girder, more particularly in brick than in stone buildings.

TENAILLE, (French,) in fortification, a kind of hornwork.

TEN-FOOT ROD, a rod used for measuring out grounds or long lengths in building.

TENON, (from the French *tenir*, to hold,) a projecting rectangular prism formed on the end of a piece of timber, to be inserted in a mortise of the same form.

Tenon-Saw, a saw with a brass or steel back for cutting tenons. *See* Saw.

TENSION, (from the Latin *tendo*, to stretch,) the degree that a piece of timber is strained by drawing it in the direction of its length.

TENSION ROD, a rod usually of wrought iron, employed to tie together any two parts of a structure which have a tendency to separate or be thrust asunder. Such are the tie-rods employed to tie the ends of the principals of a roof together, also such as are used to tie walls together to prevent their bulging, &c.

TEOCALLI, a name given to the ancient pyramidal structures of Mexico.

TEPIDARIUM, one of the apartments in a Roman bath.

TERM, (from the Latin *terminus*, a bound,) in Geometry, the same as *boundary*, or *limit*.

TERMINUS, a trunk, or pedestal, adorned at the top with the figure of the head of a man, woman, or satyr, whose body seems to be enclosed in the trunk, as in a sheath, which usually tapers downwards.

TERRA-COTTA, baked earth. This material has been much used in building and modelling both in ancient and modern times; many specimens of bas-reliefs and other ornaments in terra-cotta have been found in Herculaneum and Pompeii.

TERRACE, (from *terra*, earth,) an area raised before a house, or other building, above the level of the ground, for walking upon. The word is sometimes used for a balcony, or gallery.

Terrace-Roofs, those that are flat on the top.

TERRAS. *See* Tarras.

TERREPLAIN, in fortification, the platform, or horizontal surface of the ramparts.

TESSELATED PAVEMENT, a rich pavement of mosaic work, made of curious small square marbles, bricks, or tiles, called *tesselæ* or *tesseræ*. *See* Mosaic.

TESSERA, (from *τεσσαρα*, or *τεσσερα*, *four*,) a cube or die.

Tessera, a composition for covering flat roofs, recently invented.

TESTER or TESTOON, a flat canopy over a pulpit, &c.

TESTUDO, (from the Latin,) the horizontal vault of a church; an arched roof.

TESTUDINAL CEILINGS, or ROOFS, a word used by Vitruvius for such roofs as are in the form of the back of a tortoise.

TETRADORAN, a kind of bricks used by the Greeks. *See* Brick.

TETRAGON, (from *τετρα*, *four*, and *γωνια*, *a corner*,) a plain figure consisting of four sides and as many angles.

TETRAHEDRON, a regular solid comprehended under four equilateral and equal triangles.

TETRASPASTUS, (from τετρα, *four*, and σπασσω, *to draw*,) a machine containing four pulleys.

TETRASTYCHE, a gallery with four rows of pillars.

TETRASTYLE, (from τετρα, *four*, and στυλος, a *pillar*,) a building, or portico, with four columns in front; or a building with four pillars on a side.

THATCH, a roof or covering formed of reeds, straw, and other similar materials.

THEATRE, (from θεασθαι, *to see*,) a building used for the performance of plays, and other scenic representations.

The magnitude of a theatre must depend upon the number of spectators, and the style in which the exhibitions are intended to be got up. It would not be easy to describe in words all the apartments necessary to the construction of a theatre, nor their uses, or proportions to each other, as these must depend upon arbitrary circumstances; but the following abstract of the report of Mr. Wyatt, the architect of the present Drury Lane Theatre, with a description of the plan, will furnish a valuable elucidation.

"In arranging the design which I submitted to the committee for rebuilding Drury Lane Theatre, and which the committee have done me the honour to adopt, I have been guided principally by the considerations which are explained under the four following heads, namely: First, the size, or capacity, of the theatre, as governed by the width of the proscenium, or stage-opening, and by the pecuniary return to be made to those whose property may be embarked in the concern. Secondly, the form or shape of the theatre, as connected with the primary objects of distinct sound and vision. Thirdly, the facility of ingress and egress, as materially affecting the convenience of those going to every part of the house respectively; as well as their lives in cases of sudden accident and alarm. Fourthly, decorum among the several orders and classes of the visitants to the theatre, as essential to the accommodation of the more respectable part of those visitants, and consequently of great importance to the interests of the theatre." [Mr. Wyatt here details, under their respective heads, the space requisite for the various departments of the theatre; and then proceeds thus to the comparative width of the stage openings.] "The annexed statement of the dimensions of the stage-opening of several large theatres will be sufficient to show, that 35 feet is a very moderate width for that opening.

[The statement alluded to by Mr. Wyatt, is as follows:

Parma, 40 feet; Turin, 39; Bordeaux, 39; Argenta, at Rome, 36; Milan, 40; San Benedetto, at Venice, 40; Theatre Francais, at Paris, 40; Theatre Italien, at Paris, 33; present Theatre at Covent Garden, 37; late Theatre in Drury Lane, 46, afterwards reduced to 33 feet.]

"And although it appears, in that statement, that the stage-opening, in the theatre that was lately burnt down in Drury-lane, was laterally two feet less than that proposed in my plan, this fact is not to be received as a criterion for the dimensions most suitable to that part of a theatre; for, in the late theatre, the stage-opening was originally 46 feet; but, upon an alteration which was subsequently made in the proscenium (for the purpose of introducing stage-doors,) the breadth was reduced to 33 feet; not because a greater breadth than 33 feet was considered to be inconvenient and improper, but because the reduction to that breadth of 33 feet afforded an opportunity of combining, with the alteration above specified, the introduction of some private boxes in a part of the proscenium which would otherwise have been lost space.

"Having assumed that the size, or capacity of the theatre, must depend principally upon the width of the scene opening, and having stated the reasons for the limit which I have applied to that opening, I have next to remark upon the size of the house, as it relates to the pecuniary return for the capital embarked in the concern. It is proposed, that the largest return which can be obtained, consistently with a due attention to the interests of the public, is the legitimate right of the proprietors, and, consequently, that (after having determined the width of the stage-opening upon a suitable scale) the most capacious form which can be possibly constructed to admit of distinct vision and sound, is the form which ought to be chosen. It appears to be a very popular notion at present, that our theatres should be very small, but if that popular notion be suffered to proceed too far, it will tend, in every way, to deteriorate our dramatic performances, by depriving the proprietors of that revenue which is indispensable to defray the heavy expenses of such a concern, and to leave a reasonable profit to those whose property may be embarked in the undertaking. It should be remembered, that the unavoidable expenses attendant on any theatre of a superior order in London, (whatever be the dimensions of that theatre,) must of necessity be very great; and that less than a certain return for those expenses cannot maintain such a theatre to any good effect. Assuming the boundary which has been described as the limit of the stage-opening, and confining the front boxes (which is absolutely necessary for purposes of vision or sound) within a given distance from the front line of the stage, it is quite unquestionable, that a segment of a circle, including three-fourths of an entire circle, contains the most capacious area which can be formed within those given points; and, therefore, if that form be also one which is well adapted to distinct vision and sound, it ought, upon the principle before stated, to be chosen in preference to any other. It should be remembered, that the remarks which I am now offering, apply to the size or capacity of the theatre, as relates to the pecuniary return for capital embarked; the subject will be hereafter considered in its relations to sound and vision; in the meantime, viewing it as the form which is capable of containing the greatest number within the given limit, I shall assume it as that which the proprietors are entitled, for their own interest, to adopt. A theatre consisting of three-fourths of a circle, with a proscenium according to my plan, which shall limit the stage-opening to 35 feet, will contain, in four different heights, 78 boxes, holding 1004 persons; with four boxes (of larger size than the rest) next to the stage on each side of the theatre, capable of containing 188 spectators, in addition to the 1004 before mentioned, amounting, in the aggregate, to 1,192 persons, or £417 4 0

A pit, containing 911 persons, or	159	8	6
A two-shilling gallery for 482 persons, or . .	48	4	0
A one-shilling ditto for 284 persons, or . . .	14	4	0
Total.	£639	0	6

exclusive of four private boxes in the proscenium, and 14 in the basement of the theatre, immediately under the dress-boxes. Suppose the four private boxes in the proscenium to be appropriated to the managers, and certain other persons connected with the theatre who shall pay no rent for those boxes, the remaining 14 private boxes will let as follows: namely, the 12 smaller ones for £300 each, and the two larger ones for £500 each, for the season, (being at the rate of £23 per night for 200 nights) which, together with the foregoing amount, produces an aggregate total of £662 6s. 6d. Adverting to all the foregoing circumstances, I have no doubt that the advantages of the form which I have adopted will readily be admitted, as far as the form relates to the capacity of the theatre, and to the financial considerations

attending thereon; and I shall therefore, having shown what appears to be the best form with respect to size and capacity, now proceed to the second head of the discussion, namely, the former shape of the theatre, as connected with the objects of distinct vision and sound.—1st. With reference to distinct sound, the safest method in deciding upon the shape of a theatre appears to be, to adopt a form which is known to be in itself capable of conveying sound with facility; to construct that form of materials which are of a conductive nature; and to avoid all breaks and projections on the surface of such form, which can tend to interrupt or impede the progress of the sound when once conveyed to any part of it. It is generally admitted that a circular enclosure, unobstructed by breaks and projections, possesses the power of conveying sound with facility, and that wood is the material which combines the greatest number of desirable qualities, as to conduction, resonance, &c. &c. It does not absorb the sound so much as some materials, and does not conduct it so much as others; which medium is acknowledged to be an advantage to the clear and distinct conveyance of sound. That wood is sonorous, and capable of producing soft, clear and pleasing tones, is sufficiently demonstrated by the effect of it in musical instruments.—I shall take it for granted that whatever be the form of the theatre, it ought in every part to be confined within the limit to which the voice is known to be capable of expanding: and, certainly, I hazard nothing in assuming, that the nearer the shape shall conform to those proportions which would be described by the natural expansion of the voice, the more equally the sound will be heard in all parts of the theatre. After reading Mr. Saunders's account of the experiments upon the voice, which he describes in his *Treatise on Theatres*, I was induced to try the same experiments myself, and after changing the relative positions and distances of the speaker and hearer, in a variety of ways, and after several repetitions of each experiment, the result corresponded as nearly as possible with the statement given by Mr. Saunders, and clearly proved to me, that the natural expansion of the human voice, when moderately exerted, will be in the proportion of about two-ninths farther in a direct line, than it will laterally; and that being distinctly audible on each side the speaker, at a distance of 75 feet, it will be as plainly heard at a distance of at least 92 feet in front of the speaker declining in strength behind him, so as not to be clearly heard at much more than 30 feet from his back. Upon this principle, I have in my design made the widest of the area of the theatre, upon the level of the dress-boxes, 58 feet, allowing 9 feet 6 inches for the depths of the boxes: upon that floor, a projection of 18 inches more than is given to any of the boxes above, making together, 67 feet 6 inches between the extremity of the stage on one side, and the back wall of the boxes on the opposite side. But it should be remembered, that the speaker will not at any time be placed laterally, at the very extremity of either side of the stage, and even if he were to be sometimes so situated, the distance between him and the opposite side of the house, would be eight feet within the expansion of the voice in a lateral direction, and 27 within its limits in a direct line. Referring to all the considerations connected with the foregoing remarks, I have no hesitation in believing, that the circular form is preferable to any other form. And having, upon the principles above stated, fixed a limit for the diameter of that form, I next come to those considerations connected with sound, which ought to operate upon the longitudinal dimensions of the theatre, or upon the space from the front line of the stage, to the boxes immediately facing that line.

"It has already been stated, that the natural expansion of the human voice is about 75 feet in a lateral direction on each side of the speaker; and as it is evident the space between the front line of the stage, and the boxes immediately facing that line, may at times constitute the lateral direction of the voice, according as the actor's face shall be turned more or less towards either of the sides of the theatre, the utmost distance from the front of the stage to the back-wall of the boxes facing the stage, ought not to exceed 75 feet; or the limit to which the voice is capable of expanding in its lateral direction. For if, calculating upon the actor's face being turned (as in general it would be) towards the front of the house, the distance between that part of the house and the most advanced line of the stage, were to be considered as invariably the direct line of the voice, and were accordingly to be extended 92 feet, (the expansion of the voice in a direct line,) the consequence would be, that upon a sudden turn of the actor's head, what had before been the direct line of the sound would then become its lateral direction, and those persons, sitting at the front boxes at the distance of 92 feet from the actor, would be 17 feet beyond the reach of his voice.

"There is a form approaching very nearly to that which I have chosen, which some persons might, perhaps, on the first view of it, be disposed to prefer; I mean a semicircle, with the sides continued parallel to each other, instead of converging by continuing the circular line to three-fourths of the circle, as I have done. But upon examination, this form will be found ineligible, because it involves an extension of the stage-opening to an inadmissible width, without affording any advantage as an equivalent for that defect.—I have already stated, that the extreme distance from the front line of the stage to the back-wall of the boxes facing the stage, according to my plan, is 53 feet 9 inches; in the late theatre in Drury Lane, it was 74 feet, or 20 feet 3 inches more than mine: in the old theatre in Covent Garden, (I mean as it was built in 1730,) the distance between the front of the stage and the back of the wall of the front boxes, was 54 feet 6 inches, or 1 foot 3 inches more than mine: in the old Opera House, built by Sir John Vanburgh, in the Haymarket, it was 66 feet, or 12 feet 3 inches more than mine.—In most of the foreign theatres, it is very much greater than in my plan. At Milan it is 78 feet, or 24 feet 3 inches more: in the theatre of San Carlos, at Naples, it is 73 feet, or 19 feet 3 inches more: at Bologna it is 74 feet, or 20 feet 3 inches more: in the present theatre of Covent Garden, it is 69 feet 8 inches, or 15 feet 11 inches more. The advantages of which difference between the theatre now building in Drury Lane, and those I have just mentioned, in point of distinct sound, are obviously not less than they are with respect to vision, and they are in both so evident, that they need not be here detailed. It may be right to remark, that the theatre at Bourdeaux is exactly of the form which I have chosen; and that theatre is always quoted as one in which the voice is better heard than in almost any theatre in the world.—Before I conclude this part of the subject, I shall mention one more point, which bears very seriously upon the distinctness of sound in a theatre, namely, the uniform depth from the front to the back of the boxes throughout the house: it has hitherto been invariably the practice in our theatres, to carry the boxes facing the stage to a much greater depth than those on the sides of the theatre; and, by so doing, to produce a great difference between the form of the wall immediately at the back of the boxes, and that of the breast-work, or front of those boxes.

"Having stated my observations with respect to the advantages in point of sound which I conceive to be attendant on the circular form, I shall now offer a few remarks upon its comparative and positive merits with respect to

vision. In entering on this branch of the subject, I should wish to anticipate a question, which may possibly arise in the minds of some persons, why we should not, in the form of our theatres, adopt the semicircle, which was generally in use among the ancients, and which has evidently great advantages with respect to vision? The answer to this is, that the semicircle requires either that the stage-opening should be of enormous width, or that the size of the house should be extremely small, and therefore it is inadmissible in our theatres. It is inadmissible on the first point, namely, the enormous width of the stage as to opening, for the reasons which have been already shown (under the first head) upon that subject: and it is equally so upon the second point, because it is impossible to maintain a good theatre in this metropolis upon such a revenue as would accrue from an extremely small house. So long as the public taste for spectacle shall continue (and it is not likely to cease) all the objections to increasing the stage opening, and with it the magnitude and expense of the scenery, must remain in force. The Greeks and Romans, in their theatres, made use of scarcely any change of scenes, and their performances were given gratis to the public; consequently, their theatres were not subject to many of those considerations which are attached to ours. Under these circumstances, therefore, the semicircle is totally inadmissible for a principal theatre in London. The oval and the horse-shoe, as well as some flat-sided forms, have been supposed to be very advantageous in point of vision; but it is evident, that in the oval, a large proportion of the spectators must be placed with their backs inclining towards the scene, and that in all of them (if the house be not of extremely small dimensions) the front boxes must be at a great distance from the stage; for, in proportion as the sides shall approximate each other, the front must recede, provided the circumference be not varied.

"The fact is, there is no object connected with the formation of a theatre, which, in all its bearings, is of more importance than that that part of the house which faces the scene should be within a moderate distance of the stage; unless that be the case, it is obvious that a very large proportion of the spectators must be excluded from a clear and distinct view of that play of the features which constitutes the principal merit of the actor in many of the most interesting scenes. If the actor's merit in that particular be not fairly appreciated, he must, of course, be deprived of a proportionate share of the applause which might otherwise be bestowed on him, and this mortifying want of encouragement, bringing with it a gradual and progressive defect of zeal and emulation, cannot fail in the end to reduce the number of good actors, and materially to injure the state of dramatic performances.

"For the sake of argument, let it be supposed for a moment, that an oval, or horse-shoe, or flat-sided figure, is the best for side-vision, and the fact will then be, that, although in adopting either of those forms, provision may be made for the better accommodation of spectators sitting on the sides of the theatre, that accommodation will be given to them at a serious expense to those sitting in the front, for, while it will enable those who may sit on the sides of the house to see a greater proportion of the stage in cases of spectacles, (though not in ordinary,) those who are placed in the front will be proportionately excluded from that distinct view of the actor's countenance which is not less desirable than to be within the reach of his voice. But in point of fact, the oval, horse-shoe, or flat-sided theatre, is not so well calculated even for side-vision, as that which I have chosen; for there is one consideration of very great importance to each of these forms, and which appears entirely to have escaped observation, although obvious on reflection, namely, that although in either of them, the spectators who sit in the front row of the boxes on each side of the house, may be enabled to see rather more of the stage when extended to an extraordinary depth, those who sit in the back-seats in all the boxes above stairs, (which it should be remembered constitute in point of extent the greater part of the house,) will see considerably less of the stage than in a theatre of circular form; where, of course, the sides of the theatre will, from their swelling-shape, recede from the stage much more than in either of the others; for nothing can be more unquestionably true, than that the more the boxes on each side shall advance towards the centre-line of the theatre, the more must they necessarily overhang the stage, and all the objects on the stage; and that the more they shall overhang those objects, the more perpendicular the rays of sight (especially from the upper part of the boxes) must become, and, consequently, the less those who sit on the back-rows of the upper boxes will be able to see of the performance on the stage. In proportion as the point of sight shall be at a greater distance from the stage, the visual rays will have an oblique direction towards the stage; and a greater proportion of the breadth, as well as depth of the stage, than appears in the plan, will be opened to view in all situations. However, the comparative advantage which has been stated, namely, of seeing one-fifth more of the breadth of the stage, will belong to the circular form, a fact which I wish to impress upon the mind of the reader. There is an exemplary instance of this in the House of Commons; for, from the second row of seats on the side-gallery, (taking a position opposite the side of the table, or speaker's chair,) it is impossible to see the speaker, or any part of the floor of the house, although the whole of the seats on the opposite side of the house, upon a level with the speaker, and even below him, (being farther removed from the point of sight,) are perfectly visible; whence it is evident, that the more the position of the spectator shall recede from a perpendicular point with respect to the objects below him, the more those objects will be opened to his view: and while it is thus clear, even for the purposes of side-vision, that the oval, horse-shoe, or flat-sided theatre, is inferior to the circular form, it is, on the other hand, impossible for prejudice itself to resist the proof, that in the form I have chosen, namely, three-fourths of a circle, a much larger proportion of the whole house will be placed immediately in front of the scene, than could be the case in either of the other three forms which have been named. Impressed by the importance of all the foregoing considerations, I determined to adopt, in my design for a theatre, the form I have described; and although I was aware at the time when my drawings and model were first made, that a certain proportion of the spectators in the boxes nearest to the stage, would have but an imperfect view of the stage, I considered that as an unavoidable inconvenience in all theatres, and not greater in that projected by me, than all others; while on the other hand, the form which I had chosen, possessed many advantages which could not be derived from any other shape.—The angles, however, to which I allude, in the boxes nearest to the stage, having appeared to several persons, who saw my model, as an imperfection to the design, and those persons seeming to view the defect more in its positive than in its comparative bearing upon the perfection of a theatre, I was led to reconsider, most attentively, this particular part of the design; and after a great deal of reflection, and a variety of experiments, I determined to alter the shape of that part of the theatre adjacent to the stage, by opening the proscenium from the back, instead of from the front of the boxes. The scene (excepting in cases of spectacle) is seldom extended in depth beyond 30 feet from the front line of the stage.

"In the theatre of Parma, (which is particularly celebrated both for sound and vision,) the frontispiece of the stage-opening is placed at a distance of no less than 40 feet from the termination of the spectatory, for the purpose of opening a view of the scene to the spectators sitting nearest to the stage; and the width of the stage-opening in that theatre, with a view to the same desirable object, is extended to 39 feet, exceeding by 4 feet the width which is given to that opening of my design.

"In discussing this subject, I have hitherto confined myself to those considerations connected with the form of the theatre, which appertain directly to the two primary objects of distinct sound and vision; and I trust, that I have shown completely, that there is no admissible form so well calculated to secure those objects, as that which I have adopted in my design. But there is another consideration of great importance, which appertains to the form which I have chosen, and which does not relate to either of the objects above mentioned; namely, its decided superiority over every other form in point of beauty, for a circle is a form which will never weary or distress the eye.

"In building our early theatres in this country, little attention seems to have been bestowed upon the means of favouring sound or vision: in the form of those theatres, their sides were either entirely parallel, or diverging but little from each other; and if those theatres had not been confined to very small dimensions (such as would not be consistent with the present population and condition of the metropolis) there can be no doubt that their form would have been found to be extremely defective. The first gradation of improvement in this respect, appears to have been the introduction of the oval, and the horse-shoe, by rounding of the angles of the former shape, and thus we have been approaching gradually to that form which I now propose, and which deviates as little from the Greek and Roman amphitheatres, as the state of circumstances will admit. The original theatres of Drury Lane and Covent Garden, as well as the old Opera House, and Foote's theatre in the Haymarket, were all flat-sided; the latter (never having been rebuilt) is so to this day. The late theatre in Drury Lane was nearly oval, and the present Opera House is in the form of a horse-shoe.

"There is one other point in a great degree connected with the form and proportions of the theatre, to which I must advert, before I entirely conclude this part of the subject; namely, the height of the ceiling. In forming my design, it has been my object to avoid raising the ceiling beyond the proportion which I think it ought, for the sake of the symmetry, to bear to the open area which it is to cover: that proportion is, in my opinion, about three-fourths of the diameter of that area, but not less. I do not believe that the height of the ceiling can in any degree injure or affect the sound of the voice in the lower parts of the theatre; it may materially assist in conducting the sound into those parts of the house which are nearest to it: but it must, in every theatre, be much too high to act as a reverberator, or sounding-board, to the lower parts of the house. If this were not the fact, the voice would be quite indistinct and inaudible in a cathedral church, where the roof is at a vast height: the form of that roof, not calculated for direct reverberation of sound, and the person uttering the sound at the reading-desk, placed in a situation by no means so well calculated to convey the sound of his voice generally among his auditors, as that in which an actor upon the stage is placed: yet we know, that even under all these circumstances, the voice is heard in most of the cathedral churches quite as well as it is in many chapels; which is a positive proof that a low ceiling is not essential to the strength and clearness of sound in a theatre. If it were necessary to support this opinion, the whispering gallery in St. Paul's cathedral would serve as an additional proof, that sound may be distinctly heard in a large enclosed area (provided that area be in itself so constructed as to facilitate the conveyance of sound) without any direct reverberation from above; the great height of the dome above the floor of the whispering gallery, together with the large aperture in the centre of the dome itself, are sufficient to demonstrate, that the extraordinary effect of sound in the whispering gallery, is in no degree produced by reverberation from above. Under this conviction, I have been influenced in the height at which I have fixed the ceiling, by the proportion which appeared to me to be most in symmetry with the area to be covered by that ceiling. I feel confident, that upon a serious and impartial attention to the facts and deductions contained in the foregoing pages, it will be admitted, that the form which I have adopted is the best form: 1st, as to size and capacity; and 2nd, as to distinct sound and vision."

The following are the Dimensions of the Interior of Drury Lane Theatre.

The stage-opening, 35 feet.

The widest part of the area, upon the level of the dress boxes, 58 feet.

Depth of the dress boxes, 9 feet 6 inches.

Depth of the three upper tiers of boxes, 8 feet.

From the front line of the stage to the front of the dress boxes, in the widest part, 44 feet 3 inches.

THEATRE, among the ancients, a building encompassed with porticos, and furnished with seats of stone, or marble, disposed in the area of a semicircle, and ascending, by degrees, over each other, for the use of the spectators to behold the performances. The orchestra, or place where the musicians performed, was situate in front of the spectators. The stage, or place where the actors performed, was called *the orchestra*. The area beyond this was called *the proscenium*, or *pulpitum*. At the extremity of the proscenium stood *the scena*, a large front, adorned with the orders of architecture; and, behind, was the place where the actors made themselves ready, called *the postscenium*. *See* AMPHITHEATRE.

THEODOLITE, an instrument for taking angles, whether in a horizontal or in a vertical plane.

If 29 half-degrees of the horizontal circle be taken for the length of an arc on the vernier, and this arc be divided into 30 equal parts, the vernier will show to a single minute, by observing when a coincidence takes place between a division of the vernier and one of the horizontal circle, or limb.

THEOREM, (Greek,) a proposition which requires to be demonstrated.

THEOTHECA, (Greek, *θεος, god*, and *θήκη, repository*,) the receptacle for the consecrated host; it is of various forms and sizes, but usually of the most costly materials. The same as *Monstrance* or *Remonstrance*.

THOLE, the knop or scutcheon in the midst of a timber vault.

THOLOBATE, that part of a building on which a cupola is raised; the base of a cupola.

THOLUS, the name given to buildings of a circular form. Vitruvius employs the term to signify the roof of a circular building.

THOROUGH FRAMING, the framing of doors and windows: a term not much used at present.

THOROUGH-LIGHTED ROOMS, those which have windows on two opposite sides.

THRESHOLD OF A DOOR, the sill. *See* SILL.

THROAT. *See* GORGE, and GULA.

THROATING, the channel cut on the underside of a stone, &c., to prevent the further passage of rain, which is here collected, and drips off the building.

THROUGH-STONE, a bond stone; one which runs through the heart of the work.

TIE, (from the Saxon, *tian*, to bind,) a timber, string, chain, or iron rod, connecting two bodies together which have a tendency to diverge from each other. The tie-beams, diagonal ties, and truss-posts, are ties. Braces may act either as ties or straining-pieces: straining-pieces are preferable to ties, for these cannot be so well secured at the joints as straining-pieces.

TIE-BEAM, the beam which connects the bottom of a pair of principal rafters, and prevents them from bursting out the wall. *See* TIE and TRUSS.

TIE-ROD. *See* TENSION-ROD.

TIERCE POINT, the vertex of an equilateral triangle. Arches, or vaults, of the third point, which the Italians call *de terzo acuto*, are such as consist of two arcs of a circle intersecting at the top.

TIGE, a term used by the French for the shaft of a column.

TILE, (from the Saxon, *tigle*,) an artificial stone, or broad thin brick, made of dried earth, and burnt in a kiln, used in covering buildings. *See* BRICK.

Tiles have various names, according to their surface, shape, or situation.

Those of a rectangular form, with a plane surface, are denominated *plane tiles* and *crown tiles:* their dimensions are about 10½ inches long, 6 inches broad, and five-eighths of an inch thick. A plane tile weighs from 2 lb. to 2½ lb.

Those of a cylindric form are denominated *ridge tiles, roof tiles*, or *hip tiles*, and are used in covering the ridges of houses. Their dimensions are, in length, about 12 inches, in breadth 10, and in thickness five-eighths of an inch. The weight of a ridge tile is about 4½ lb. Tiles which are placed on the angle formed by the two sloping sides, are called *hip tiles.*

Tiles to be placed in gutters, have a form adapted to their situation: the weight of a gutter tile is the same as that of a ridge tile.

Tiles of a rectangular outline, with a surface both concave and convex, are denominated *pan tiles;* these have no holes, but are hung on the lath, by means of a ledge, formed in their making, at their upper ends: they are usually 14½ inches long, and 10 broad. They weigh from 5 lb. to 5¼ lb.

TILE-CREASING, two rows of tiles placed horizontally under the coping of a wall, and projecting about three inches from the surface, for discharging the rain-water therefrom.

TILES, ENCAUSTIC, decorative tiles formed of different-coloured clays, arranged so as to form a variety of patterns. The ground is usually red, and this being stamped with some pattern, the recess is filled in with clay of various colours, frequently white, the whole being afterwards glazed over with a yellow glaze. Frequently each tile presents a complete pattern, but at other times a pattern is composed of four or more tiles arranged in juxtaposition. Such tiles are mostly used in ecclesiastical buildings, and are often interspersed in regular order amongst tiles of a plainer description, by which means their beauties are more fully displayed.

TILING, the act of laying tiles for the covering of a building, which may be done either with plane tiles or pan tiles. Plane tiling is preferable to pan tiling. Plane tiles are laid at a 6-inch gauge, with or without mortar; and pan tiles at an 11 or 11½ inch gauge, though some use a gauge of 12 inches, but this distance is too great.

From the frequent repairing of tiled roofs, and their fiery appearance, slating has now become the general covering, and tiling is seldom used except for common cottages, sheds, and out-houses, as being more expensive to keep in repair than slating.

TIMBER, (from the Saxon, *timbrian*, to build,) in carpentry, a piece of wood for supporting some part or parts of the building, or to give strength to any part thereof.

Timbers, in a building, support parts of the fabric in three different ways, viz., by lateral strain, by tension, and by compression.

TIMBER, wood felled and seasoned for the purpose of building. Many kinds of woods are useful for building purposes, but those most frequently employed are oak, fir, and pine; but before entering into the peculiar properties of these, it will be as well to give some idea of the structure and growth of trees in general.

Upon observing the transverse section of the stem or trunk of a tree, the wood will be found to be composed of numerous concentric layers or rings, which are more or less defined in different trees. Where the rings are well defined, they will be found to consist of two parts, the outer being hard, compact, and of a dark colour, while the inner is of a lighter tint, more soft and porous. In the centre of the tree is the pith, and on the exterior the bark, and it will be observed, that the concentric rings become more soft, and contain more sap as they recede from the pith, the more compact layers nearest the pith being termed heart-wood.

The structure of a tree appears to be composed of minute vessels for conveying nutriment from the roots; the space between these vessels being occupied by cells, which are engaged in performing the function of secretion. The vessels in the growing tree convey the sap in a liquid state from the roots to the leaves, whence it descends in a less liquid state through the bark, and is at last deposited in an altered state between the bark and the last year's wood, forming a new layer of bark and sap-wood, the old bark being pushed outward, and the inner layers being compressed, probably in an equal degree. The sap begins to ascend in the spring of the year, and flows principally through the annual rings next the bark, which contain most sap-wood. In its ascent, it would appear to dissolve some part of a substance which had accumulated in the vessels during the preceding winter, for the nourishment of the buds, leaves, and new wood; and this accounts for the viscous state of the sap on its descent. As the leaves expand, the sap ceases to flow, and the bark again adheres to the wood, and, from the middle of June to the middle of August, there appears to be a pause in vegetation; but after this period, the sap again begins to flow.

As this process goes on from year to year, the fluid parts of the interior of the wood, are absorbed by the new wood and leaves, and the vessels through which they flow, being pressed more closely together by the growth of new wood, become harder and harder, until at last the sap-wood is converted into heart-wood; for it would appear, that there is nothing of the character of solid fibres in wood, the more compact parts being composed solely of the linings of the vessels and cells deprived of their moisture, and packed closely together. When trees arrive at this stage of existence, that is to say, when the sap-wood has become heart-wood, and the greater part of the moisture has been expelled, they are in a fit state to be felled for the purposes of building. The best time for felling is in mid-winter or midsummer; for in the former the sap has ceased to flow, and in the latter it is expended in the production of leaves. Besides the concentric rings, another series of lines may be observed with more or less facility in the sections of various trees;

these lines radiate from the centre, and are termed medullary rays; they produce that beautiful flowered appearance in the oak, to which the name of silver grain has been given.

It will not be necessary here to treat of the seasoning of timber, as that subject has been treated on in another place. *See* SEASONING OF TIMBER.

If timber be properly seasoned, and kept in a dry situation, with a free circulation of air, it will last for several centuries, but even under the most favourable circumstances it gradually deteriorates, it loses its elastic and coherent properties, and becomes brittle at last. If it be kept immersed in water, it will also last a very considerable period; but it is not uninjured, for if it be taken out and dried, it becomes brittle, splits, and cracks in every direction. Alternate changes of dryness and moisture is very injurious to timber, and under such conditions it rapidly decays, as may be observed in the upper part of piles driven in a tidal river, viz., that part which is contained between high and low water. Moisture, combined with a certain degree of heat, about 45 degrees, will gradually decompose timber, especially when exposed to the air. This rot is usually divided into two kinds, the wet and dry rot; these, however, are both produced by the same causes, the only difference being that the former takes place when there is a free evaporation, the latter when the evaporation is imperfect; the one takes place when there is a free circulation of air, the other when the air is confined.

The best method of preserving timber, and preventing decay from any of the above causes, is by proper seasoning, but it must be thoroughly seasoned, partial seasoning being of little avail. A coating of paint, tar, or other preparation, will help to defend the wood from injury by external causes, but will be of no service if any moisture remain in the interior, for it will only prevent its escape, and thus hasten decay. Paint is also useless, unless fresh coats be repeatedly applied, for it is as liable to decay as the timber itself, and therefore requires to be constantly renewed. If the paint be sanded over, it will be found much more durable than common painting. A very good preparation consists of linseed oil and tar put on boiling, the wood being first thoroughly heated; this will sink into the wood, and close up all the pores. Charring the wood will be found an excellent method, and is in many respects better than some of the above. No composition should, however, be applied till the timber has been well seasoned, for to inclose the natural juices of the wood, is to render its rapid decay certain.

Description of Woods.—Of oak there are several kinds, two of which belong to England—the common British oak, and the sessile-fruited oak. The first is found in the temperate parts of Europe, and is that which is commonly met with in the south of England. The wood has often a reddish tinge, and the larger septa are very numerous, producing large flowers; the grain is tolerably straight and fine, and free from knots. It splits freely, and makes good laths for plasterers and slaters; and is decidedly the best kind of oak for joists, rafters, and for any other purposes where stiff and straight-grained wood is required. The second kind is found in the temperate parts of Europe, and in the north of England; it is of a darker colour than the preceding, and the larger septa are fewer in number; the grain is smooth and glossy. It is heavier, harder, and more elastic, and is apt to warp and split in seasoning; it is tough, and difficult to split.

The Dursault oak is a native of France and the south of England, but it is not so strong nor of so firm a texture as the above. The wood of the Austrian and American species is not very valuable; the former being comparatively soft and the latter coarse-grained. The mountain red oak, from Canada, is useful for many purposes, but is light and spongy, and not very durable. The white oak, also from America, is more valuable, being tough and pliable, and more durable than the other species.

The colour of oak is a fine brown of various shades; that inclined to red is the most inferior kind. The transverse septa are usually large and distinct, but are smaller and less distinct in the stronger kinds of wood. The texture is alternately compact and porous.

Oak is particularly adapted for situations exposed to the weather, and makes the best wall-plates, ties, templets and king-posts, but is liable to twist and warp when drying.

Beech is not much used for building, and soon rots in damp situations; in dry situations it is more durable, but is liable to be injured by worms; it is best adapted for piles and other works where it is constantly immersed in water. It is stronger and tougher than oak, but not so stiff. The colour is whitish-brown, of different shades; the texture is very uniform, and the septa smaller than in oak.

Alder has much the same qualities as beech, being very durable in water, but rotting when exposed to damp, and subject to worms in a dry state. The colour is reddish yellow of different shades, and nearly uniform; the texture is very uniform, with larger septa of the same colour as the wood. It is soft, and works easily.

Of plane trees, that from America is very durable in water, but they are not much used for building purposes. The colour and structure is similar to that of the beech, but in this case the septa are more numerous.

Chesnut may be used in many places as a substitute for oak, the wood is hard and compact; when young it is tough and flexible, but when old it is brittle and often shaky. It does not shrink and swell much, and is easier to work than British oak, and contains only a small proportion of sap wood.

The wood of chesnut is so much like that of oak, that it has frequently been mistaken for it; it has, however, no large transverse septa, and in old wood the sap-wood is whiter, and the heart-wood browner, than in oak.

Ash is superior to any other British timber for its toughness and elasticity; it is tolerably durable in a dry situation, but soon rots when exposed to damp or alternate changes of wet and dry. It is too flexible for the timbers of buildings, and in old trees is of a brittle nature. The colour is oak brown, the veins being darker than in oak; in young trees, however, the colour is lighter. The texture is alternately compact and porous, the rings being strongly marked; there are no large septa.

Elm is not much used for building; it is very durable in water, as also when perfectly dry, but will not stand exposed to the weather. It is difficult to work, but not liable to split; it twists, shrinks, and warps much in drying. The heart-wood is generally darker and redder than that of oak, and the sap-wood of a yellowish or brownish white; it is porous and cross-grained, but has no large septa.

The common acacia is very durable; it is equal or superior to oak in stiffness and toughness, and is very valuable for fencing. The colour is a greenish yellow, with a slight tinge of red in the pores, and is, in structure, alternately compact and very porous, so that the rings are very distinct; it has no large septa.

There are several species of poplars, of which the Lombardy, black, and common white, are mostly esteemed. They are all very durable when preserved in a dry state; and the aspen or trembling poplar will last a considerable time exposed to the weather. They are not well adapted for large

timbers, but are well fitted for flooring, where there is no great wear, they do not take fire readily.

The colour is of a yellowish or brownish white, one side of the annual rings being a little darker than the other. The wood is of a uniform texture, and has no large septa.

Red or yellow fir is the produce of the Scotch fir, and is common in the north of Europe, in Scotland, Russia, Denmark, Sweden, Norway, and Lapland. It is very durable; and its lightness and stiffness render it superior to any other material for beams, girders, joists, rafters, and framing in general. It is also much used for joiners' work, both external and internal, being cheaper and more readily worked than oak. The wood from cold climates is stronger than that from warmer situations. The colour is of a reddish or honey-yellow, and of various degrees of brightness; the layers are well marked, the one part being soft and light-coloured, the other hard and dark: in the best timber the rings are thin, not more than $\frac{1}{10}$th of an inch in thickness. The inferior kinds have thick annual rings; in some kinds the dark parts of the rings are of a honey-yellow, the wood, heavy, and filled with soft resinous matter, feels clammy, and chokes the saw. In other inferior kinds it is spongy, contains less resinous matter, and leaves a woolly surface after the saw.

White fir, or deal, is the produce of different varieties of spruce fir, and is imported from the north of Europe, and from America. Of Norway spruce, a great quantity is imported from Christiana in deals and planks, which are very highly esteemed. The American wood is not so resinous as that from Norway; it is tougher, less heavy, and generally more liable to twist in drying. It is of two kinds, white and black spruce, the latter producing the best wood. White deal is very durable in a dry state, and is much used for internal joiners' work.

The colour is yellowish or brownish white; the hard part of the annual ring a darker shade of the same colour, often has a silky lustre, especially in the American and British-grown kinds. Each annual ring consists of two parts, the one hard and the other softer. The knots are generally very hard. The clear and straight-grained kinds are often tough, but not very difficult to work, and stand extremely well when properly seasoned.

The Weymouth, or white pine, is a native of North America, and is imported in large logs, often more than 2 feet square, and 30 in length: it is one of the largest and most useful of the American pines. The wood is light and soft, and is said to stand the weather tolerably well. In joinery it is much used for mouldings and other work, where clean straight-grained wood is desirable; but it is not durable, nor fit for large timbers, being very liable to take the dry-rot. The colour is brownish yellow, and the texture more nearly uniform than that of any other of the pine species, and the annual rings not very distinct.

The pitch pine is a native of Canada. It is very resinous and heavy, but not very durable: it is also brittle when very dry. It is of a redder colour than the Scotch pine, feels sticky, and is difficult to plane.

The silver fir is a native of the mountains of Siberia, Germany, and Switzerland, and is common in British plantations. The wood is of a good quality, and much used on the continent both for carpentry and ship-building. The harder fibres are of a yellow colour, compact and resinous; the softer nearly white. It is light and stiff, and does not bend much under a considerable load; consequently floors constructed of it remain permanently level. It is subject to worm.

Of the larch there are three species; one European, and two American. The wood is extremely durable in all situations, even when exposed to damp and weather; it is adapted for both internal and external work, and especially for flooring boards, which are subject to much wear; also for doors, shutters, &c.

The wood of the European larch is generally of a honey-yellow colour, the hard part of the annual rings of a redder cast; sometimes it is brownish white. In common with the other species of pine, each annual ring consists of a hard and soft part. It generally has a silky lustre, and its colour is browner than that of the Scotch pine, and it is much tougher. It is more difficult to work than Riga or Memel timber, but the surface is better when once it is attained. It bears driving bolts and nails better than any other kind of resinous woods. When it has become perfectly dry it stands well, but warps much in seasoning.

The following table, showing the comparative strength, stiffness, and toughness of various woods, taking English oak at 100 as a standard, is compiled from Tredgold, from whose work the above observations are principally extracted:—

Name of Wood.	Strength.	Stiffness.	Toughness.
Common English Oak	100	100	100
Riga Oak	108	93	125
American Oak	86	114	64
Dantzic Oak	107	117	99
Beech	103	77	138
Alder	80	63	101
Plane Tree	92	78	108
Sycamore	81	59	111
Green Chesnut	68	54	85
Ash	119	89	160
Elm	82	78	86
Unseasoned Acacia	95	98	92
Spanish Mahogany	67	73	61
Honduras Mahogany	96	93	99
Walnut	74	49	111
Teak	109	126	94
Abele Poplar	86	66	112
Lombardy Poplar	50	44	57
Cedar	62	28	137
Foreign Fir	80	114	56
Mar Forest Fir	61	49	76
English-grown Fir	60	55	65
Christiana Deal	104	104	104
American White Spruce	86	72	102
British-grown Norway Spruce	70	81	60
Weymouth Pine	95	99	103
Pitch Pine	3	82	92
Larch	103	79	134

For further information on this head, see STRENGTH OF MATERIALS.

TIMBER BRIDGE. *See* WOODEN BRIDGE.

TIMBER MEASURE, 43 solid feet make a ton of timber, and 50 feet a load.

TIMBER PARTITIONS, are board and brace, or quarter or stud partitions. Board and brace partitions are made of narrow boards, or battens, with a thin board between every two battens inserted into their edges: the batten is about half the width of a board.

TIN, a very useful metal, found principally in Cornwall. It is of a silvery-white colour, with a very slight shade of yellow; it is very soft and malleable.

TING, a Chinese temple. *See* CHINESE ARCHITECTURE.

TINNING. The process of covering other metals with tin for the purpose of preventing rust or oxydation. The practice was very commonly adopted in mediæval metal-work.

TOMB. The custom of interring the dead seems to be more ancient than that of burning, and in many countries we

find that great pains were taken to preserve them by embalming and similar methods. The practice of burning the bodies would seem to be of later date, and at no period of time universal; under these circumstances, however, the ashes were usually preserved with great care in some structure set apart for that especial purpose. Great reverence has always been shown for the bodies of the departed; a feeling which has been exhibited in different manners, according to the time and place: the interment would appear to have been always connected with some religious rite. In some places, the bodies were simply inhumed or deposited in the earth without any erection above them, save that of a tumulus of earth; in others, they were embalmed at great expense, and placed in structures of greater or less magnificence; whilst in others again they were deposited in natural caves or excavations beneath the surface of the earth.

Perhaps no people have ever expended greater care upon their dead than the Egyptians, a fact which may be readily accounted for by the tenets of their religion. This nation was accustomed to adopt both the latter practices, as is manifest by their building those vast structures, the pyramids, which have been proved to have been erected for the purpose, as well as by the existence of an extensive range of excavations below the surface of the ground. Of the latter, as well as of the pyramids, will be found an account under the article Egyptian Architecture, and of the Pyramids, under that article.

Many sepulchral grottos have been found in the plains of Etruria. They are hollowed out of a rock, sometimes disposed in the form of a cross, or with three wings, and sometimes squared in different proportions. Doors have been formed to lead from one grotto to another; sometimes they are above each other. These grottos are not very deep, and the interior is often adorned with paintings. In Campania, also, several tombs have been discovered, containing Etruscan vases. They are represented as being formed by an enclosure of cut stones, and covered with a sort of roof or flagstone shelving on both sides. The dead body was stretched out on the ground, the feet turned towards the entrance of the sepulchre, and the head ranged against the wall, from which were suspended, by bronze nails, vases of terra-cotta, whilst others of a similar kind were disposed around the body.

At Agrigentum, the tombs are a sort of troughs ranged one above another, sometimes arched, or chambers with rent-holes in the roof, only two inches apart from each other. In some parts of Greece and Italy are sepulchral chambers excavated in the rock, and formed like a bell, as at Amphissa. In the valley of Ispica, in Sicily, Denon found tombs, formed out of a hollow stone, upwards of 5 feet long and 15 inches wide.

Tumuli, or large mounds of earth, are of very ancient date, and are to be found in various situations. They are frequently found encompassed by a large square wall, as that of Alyattes in Lydia, of Ægyptus in Arcadia, and of Phocus in Ægina besides many others in Greece and Asia, and in western Scythia. In one, with a circular wall, which was opened between Smyrna and Pergamus, were found galleries and chambers. One of the tumuli in the plain of Athens having been opened, was found to contain a chamber finely constructed of large blocks of stone, in which was a vase of terra-cotta, with figures and inscriptions.

Of a similar kind, though of smaller dimensions, were those mounds which are termed barrows, and which are common in many parts of Europe and Asia. "The Russians, in effecting a practicable road to China, discovered, in fifty degrees north latitude, between the rivers Irtish and Obalet, a desert of very considerable extent, overspread in many parts with tumuli or barrows." One of the largest of these barrows was opened by the Russian government, and was found to contain the body of a prince. "After removing a very deep covering of earth and stones, the workmen came to three vaults constructed of stones of rude workmanship. That wherein the prince was deposited, which was in the centre, and the largest of the three, was easily distinguished by the sword, spear, bow, quiver and arrow which lay beside him. In the vault beyond him, towards which his feet lay, were his horse, bridle, saddle, and stirrups. The body of the prince lay in a reclining posture upon a sheet of pure gold, extending from head to feet, and another sheet of gold of the like dimensions was spread over him. He was wrapped in a rich mantle, bordered with gold, and studded with rubies and emeralds. His head, neck, breast, and arms naked, and without any ornament. In the lesser vault lay the princess, distinguished by her female ornaments. She was placed reclining against the wall, with a gold chain of many links set with rubies round her neck, and gold bracelets round her arms. The head, breast, and arms were naked. The body was covered with a rich robe, but without any border of gold or jewels, and was laid on a sheet of fine gold, and covered over with another. The four sheets of gold weighed forty pounds. The robes of both looked fair and complete, but, upon touching, crumbled into dust." The tombs near Pergamus in Asia Minor are cones of earth with chambers or vaults constructed in the interior. The tomb of Anthridates in the Crimea, is an immense tumulus of hemispherical form, constructed with huge masses of stone of an irregular shape, heaped together without the aid of cement of any kind. This kind of construction is the same as that to be found at Tyrus and Mycene, and is supposed to have been of very ancient date. *See* Pelasgian Architecture.

The Romans do not seem to have adopted this kind of sepulchre, for although tumuli have been discovered in this country containing articles of Roman workmanship, yet our best antiquaries do not allow such to have been the burial-places of the Romans themselves, but rather of Romanized Britons, or of Britons engaged in their service. The general characteristics of a Roman place of interment in Britain, appear to consist simply of the plain grave, with one or more stone pillars bearing an inscription, and sometimes a sculptured device. At Chatham hill in Kent, a Roman sepulchre was discovered, of which the walls were composed of rubble-stone and hard mortar; the wall first discovered was 30 feet in length, and intersected by three apartments with their walls. One apartment which was complete, was 9 feet 3 inches by 7 feet 3 inches, with the inside of the walls covered with fine white plaster, on which were painted stripes of black and red. The urn containing the ashes of the deceased, was deposited on a pavement within the sepulchre, and round it were several vessels of different size and shape, pateræ, &c. A Roman sepulchre, discovered about two hundred and fifty yards from the wall of the city of York, was an oblong room with a ridged roof, covered with hollow Roman tiles; it was about $3\frac{1}{2}$ feet long within, and contained several urns all standing on a tiled pavement. A burial-vault was discovered in Oxfordshire, which in the part explored was 20 feet long by 18 wide, and 8 high from the planking-stones. The human remains were laid in partitions of a dissimilar width, which crossed the vault from east to west, and were built with Roman red tiles, about $8\frac{1}{2}$ inches square. The partitions were $2\frac{1}{2}$ feet deep, and generally about the width of modern graves. Roman urns and other vessels were discovered among the rubbish. There were two tiers of sepulchral recesses, and above were a range

of planking covered with mortar and sand, in which was set tesselated work, supposed to have formed the flooring of a temple." In the year 1807, a Roman vault containing a scarcophagus, was discovered in the suburbs of York. The sarcophagus, which contained a skeleton, was cut out of a single grit-stone, and covered with a blue flagstone; its length was 7 feet; breadth 3 feet 2 inches; depth 1 foot 6 inches; thickness 4 inches. Near the vault, an urn of red clay was discovered, containing ashes and fragments of burnt bones. Stone coffins of a similar character, containing bones accompanied by urns, &c., have frequently been discovered. Coffins of brick also occur.

The tumuli, not unfrequently discovered in this island, are to be attributed for the most part to the Britons, as is often evidenced by the weapons, &c. found within them. The Saxons, however, it is probable, still continued the practice, though not for a very long period; their barrows are distinguished from the British by being devoid of any remains of garments, &c.; they are found in clusters, and are of the bell-shaped form. Those with cistvaens, urns, cups, beads, weapons in wooden scabbards, bosses of shields, &c. are British. The cistvaens, just mentioned, consist of three or four stones placed edgeways, and covered by another at the top. Several Saxon barrows are still to be seen in Lower Saxony. The custom of interring the body commenced to be practised by the Saxons, in all probability, upon their conversion to Christianity: their coffins were either of wood or stone, the latter being reserved for persons of wealth and influence; they were at first made of several stones, set round with one at the bottom, and one for a cover at the top, similar to the British cistvaens, but they were afterwards formed of a single stone, hollowed out, with a slab for a cover. In the earlier periods, the bodies of all persons were interred in the cemetery which surrounded the church, but in a short time, persons of rank, and ecclesiastics, began to be buried within the church; and, in such cases, the top of the coffin was generally level with the pavement, of which, indeed, it formed a part.

After a time, the tombs began to assume a different form, and became gradually of a more costly and imposing character. From the plain stone chest we come to that with a coped covering; and then we find the lid sculptured with some ornament, most frequently with a cross, plain or floriated. Next, we arrive at the raised tomb, which became more and more ornamented; and at last we have them covered with rich canopies, and embellished with the most minute and delicate carving. Some tombs in our larger churches and cathedrals still exist as specimens of the most elaborate workmanship of our ancient artificers. Stone tablets, inlaid with brass, were for some time common; the brasses which were engraved, represented the deceased in his usual costume, sometimes surrounded with a canopied niche, also of engraved brass, let into the slab, and usually having a border of inlaid brass round the edge of the slab, containing an inscription relative to the title of the deceased. Floriated crosses, and other figures, were sometimes inlaid in a similar manner; and, occasionally, the brasses were enriched with coloured enamel. Remains of brasses are very common, few old churches being without them.

During the whole of this period, burials in the church-yard were still common, tombs within the church being reserved for the great and noble. The church-yard stones were, of course, of a more simple description, being either of wood or stone, and most usually in the form of a cross, varying, however, greatly in design and outline.

After the Reformation, sepulchral monuments, together with architecture, began to decline in taste and execution; in design, they follow the prevailing style of architecture and we find Italian details gradually introduced. Effigie were common; and it is not uncommon to find, during the Stuart period, effigies of an entire family on one tomb. Brasses were still prevalent, though of less beautiful design and workmanship. After this, the Italian, or rather Elizabethan style, was thrown aside, and we find groups of sculpture, of classic design, more or less successful, some of very extensive dimensions; in fact, at one time, size seems to have been the principal recommendation, as will be evident to any one visiting our cathedrals, where he cannot but lament the introduction of huge monstrosities, equally vicious in design and execution; and for the sake of these, too, he will see windows and arches blocked up, delicate workmanship defaced, and the whole effect of a grand design marred, if not destroyed. The ill taste displayed in the designs, and the monstrous adulation portrayed in the inscriptions of the monuments of the last century and a half, is enough to shock the feelings of any man who pretends to modesty or common sense. We are glad to see a better taste reviving in the present day.

Mr. Gough has classified the tombs of this country under eight different heads as follows:—

1st Form.—Coffin-shaped stone, prismatic and plain at the top.

2nd Form.—Prismatic and carved at the top, with crosses plain and fleury, as that of Theobald, Archbishop of Canterbury, in 1160, and that of Bishop Glanville, near the altar in Rochester Cathedral.

3rd Form.—Tables with effigies or sculpture, as that of Robert Duke of Normandy, in Gloucester Cathedral, with effigy cross-legged, in a coat of mail, A. D. 1134; King John, in Worcester Cathedral, 1213; Prelates in pontifical habits, first in half-relief, afterwards complete effigies, as Herbert Walter, Archbishop of Canterbury, 1205; Knights and nobles in armour, &c., as Longspee, Earl of Salisbury, 1226.

4th Form.—Tombs with festoons or arches over them, as those of Henry III., Edward I., Queen Eleanor, Edward the Black Prince, Henry IV., &c. This class was succeeded by more lofty tombs, with arches, crochets, pinnacles, finials, &c.

5th Form.—Tombs in chapel burial-places, consisting mostly of open screens, with doors, altar, monuments, piscinas, niches, &c., several of which are seen in the cathedrals of Wells, Salisbury, Exeter, &c.

6th Form.—Inlaid with brass, representing figures of the deceased, and inscriptions either in cameo or intaglio. These are mostly of the 14th century. Many fine specimens are engraved and published by Cotman.

7th Form.—Against walls, which chiefly occur since the Reformation.

8th Form.—Detached buildings, as domes, obelisks, columns, and equestrian statues.

TONDINO, a round moulding, representing a ring. *See* TORUS.

TONGUE, (from the Saxon *tung*,) a projecting part on the edge of a board, to be inserted in a groove ploughed in the edge of another. Instead of a tongue wrought out of the edge of the solid board, sometimes both the edges to be joined are ploughed, and a tongue is made equal to the sum of the depths of both grooves, and being inserted into one of them, they are then driven home to each other. It is very difficult to glue two edges that are grooved and tongued together, unless the tongue be made very slack, on account of the difficulty of rubbing them. Work that is tongued should not be fastened with glue; white-lead and oil should be used in preference.

TOOLS, (from the Saxon *tol*,) implements used by artificers in the reduction of any material to its intended form.

The tools employed by the different professions of artificers in building are chiefly carpenters' tools, bricklayers' tools, joiners' tools, masons' tools, slaters' tools, and tilers' tools.

The bricklayers' tools have already been described under the article BRICKLAYER, it only remains here to give the reference to the Plate:

Figure 1.—The *trowel.*
Figure 2.—The *brick-axe.*
Figure 3.—The *square.*
Figure 4.—The *bevel.*
Figure 5.—The *jointing-rule.*
Figure 6.—The *jointer.*
Figure 7.—The *hammer.*
Figure 8.—The *raker.*
Figure 9.—The *line-pins.*
Figure 10.—The *rammer.*
Figure 11.—The *pickaxe.*
Figure 12.—The *camber-slip.*
Figure 13.—The *banker*, with the *rubbing-stone* placed upon it.

The carpenters' tools having been more slightly noticed, we shall here show their uses as they are referred to in the Plate.

Figure 1.—The *axe*, used in chopping timber by a reciprocal circular motion, with the cutting edge of the axe in a vertical plane.

Figure 2.—The *adze*, used in chopping timber by a reciprocal motion in a given plane, which is generally that of a vertical plane, but with the cutting edge describing a cylindric surface.

Figure 3.—The *socket-chisel*, used in mortising large timbers; and as the mortise is commonly bored by the auger, the chisel is generally less than the breadth of the mortise.

Figure 4.—The *mortise-gauge*, with a double tooth, made temporarily to serve only for the framing in hand.

Figure 5.—The *square*, used in forming right angles, and taking any kind of angles by observing the numbers on the sides of the square.

Figure 6.—The *plumb-rule*, used in setting work perpendicular.

Figure 7.—The *level*, used in setting work horizontal by means of the double square.

Figure 8.—The *auger*, for boring pin-holes, or holes in mortises, for the more easy cutting with the socket-chisel.

Figure 9.—The *hook-pin*, used in drawboring, or in bringing the parts of a large frame together.

Figure 10.—The *crow-bar*, for moving large pieces of timber.

References to Joiners' Tools. *See* JOINERY.

Plate I. *Figure* 1.—The *jack-plane; a* the stock; *b* the tote, or handle, which being open on one side, is called *a single tote; c* the iron; *d* the wedge; *e* the orifice, where the shavings are discharged. *See* PLANE.

Figure 2.—The *trying-plane.* The parts are the same as those of the jack-plane, except that the hollow of the tote is surrounded with wood, and on this account it is called *a double tote.*

Figure 3.—The *smoothing-plane*, without a tote, the hand-hold being at the end of the plane.

Figure 4.—The *iron.* No. 1, Front view of the cover for breaking the shavings, screwed on the top of the iron, to prevent the tearing of the wood. No. 2, Front of the iron without the cover, showing the slit for the screws which fasten the cover to the iron. No. 3, The profile of the iron and cover screwed together.

Figure 5.—The *wedge*, for lightening the iron. No. 1, The longitudinal section of the wedge. No. 2, Front, showing the hollow below, for the head of the screw.

Figure 6.—The *sash-fillister*, for throwing the shavings on the bench; *a* head of one stem; *b* tail of the other; *c* iron; *d* wedge; *e* thumb-screw, for moving the stop up and down; *f f* fence for regulating the distance of the rebate from the arris. *See* PLANE.

Figure 7.—The *moving-fillister*, for throwing the shavings on the bench. No. 1, Right-hand side of the plane: *a* brass stop; *b* thumb-screw of ditto; *c d e* tooth; the upper part *c d*, on the outside of the neck, and the part *d e*, passing through the solid of the body, with a small part open above *e* for the tang of the iron tooth; *f f* the guide of the fence. No. 2, Bottom of the plane turned up: *a* the guide of the stop; *f f* the fence, showing the screws for regulating the guide; *g g* the mouth and cutting edge of the iron.

Figure 8.—The *plough*, being the same in every respect as the sash-fillister, except the sole, which is a narrow iron. *See* PLANE.

Figure 9.—The *mallet.*
Figure 10.—The *hammer.*
Figure 11.—The *side hook*, for cutting the shoulders of tenons.

Figure 12.—The *work-bench: a* the bench-hook; *b b* the screw-cheek; *c c* handle of the screw; *d* end of the guide.

Plate II. *Figure* 1.—The *stock*, into which is fixed a *centre-bit.*

Figure 2.—No. 1, The *gimlet;* No. 2, The lower part, at full size.

Figure 3.—No. 1, The *bradawl;* No. 2, The lower end turned edgewise; No. 3, The lower end turned sideways.

Figure 4.—No. 1, The *paring chisel;* No. 2, The lower end turned edgewise with the basil.

Figure 5.—The *mortise chisel.* No. 1, The side; No. 2, The front; No. 3, The lower end, with the basil.

Figure 6.—The *hand saw.* *See* SAW.

Figure 7.—The *tenon saw;* generally backed with iron.

Figure 8.—The *sash saw;* generally backed with brass.

Figure 9.—The *compass saw*, for cutting in the direction of a curve-line.

Figure 10.—The *key-hole saw: a* the pad, in which is inserted a spring and two screws for fixing the saw to any length.

Figure 11.—The *square: a b c* the outer square; *d e f* the inner square; *a d e* the stock, or handle; *b c f e* the blade.

Figure 12.—The *movable bevel: a b* the stock; *b c* the blade.

Figure 13.—The *gauge: a a* the stem; *b b* the head, which moves; *c* the tooth, for cutting a sharp line on the surface of the wood. *See* GAGE.

TOOLS, *Masons'*, are: 1. The *peck*, or *cavil*, for breaking and dressing the stone to any determinate size. 2. *Points* from $\frac{1}{8}$ to $\frac{1}{4}$ of an inch, for quickly reducing the prominent parts of a stone.

3. The *chisel*, from half an inch to two inches in breadth

4. The *tool*, from two inches to two and a half or three inches in breadth.

5. The *mallet.*

As points will reduce the solid more than chisels, so will a narrow chisel reduce the solid more than a broad one; but the broader the chisel, the smoother the work; and hence broad chisels, or tools, are always used in the finishing of work. The tools here enumerated belong to the journeyman, but the master requires many others of a more extensive nature, as cranes, and other machines for hoisting up stones.

TOOLS, *Plasterers'*. *See* PLASTERER.

Tools, *Plumbers'*. *See* Plumber.

Tools, *Slaters'*. *See* Slating.

Tools, *Tilers'*, are: 1. The *lathing hammer*, with two guage marks; one mark is placed at 7 inches, the other at 7½. This tool is used both for lathing and tiling.

2. The *lathing staff*, of iron, in the form of a cross, to stay the cross laths, and clinch the nails.

3. The *tiling trowel*, to take up the mortar and lay it on the tiles. It differs from the brick trowel in being longer and narrower.

4. The *bosse*, made of wood, with an iron hook to hang on the laths, or on a ladder for holding the mortar and tiles.

5. The *striker*, a piece of lath about ten inches long, for separating and taking away the superfluous mortar at the breeches of the tiles.

6. The *broom*, to sweep the tiling after it is strook.

TOOTH, the iron or steel point in a guage, which marks the stuff in its passage, or draws a line parallel to the arris of the piece of wood.

Tooth Ornament, a sculptured ornament common in and characteristic of buildings of the early English style of architecture. It consists of a sculptured flower of four leaves, disposed in a pyramidal form; the centre, where the leaves join, projecting above the general surface, to which it is applied as a decoration. It is commonly inserted in hollow mouldings, disposed either at intervals, or more frequently in close proximity one to the other. Its origin is naturally derived from the junction of two Norman zig-zag mouldings meeting at an arris. *See* Dog-tooth Moulding.

TOP BEAM, the collar-beam of a truss: it has also been called *wind-beam*, or *strut-beam*. Collar-beam is now generally used, the other names being either antiquated or not much employed. *See* Collar-Beam.

Top Rail, the uppermost rail of a piece of framing, or wainscoting, as its name imports.

TORSEL, or Torsil (from the French *torse*,) a piece of wood laid into a wall, for the end of a timber, or beam, to rest on. *See* Tassels.

TORUS, or Tore, (Latin,) a large moulding, of a semicircular section, used in the bases of columns. The only difference between an astragal and a torus is in size, the astragal being small, and the torus large.

Torus for a Bulwark, a large semicircular moulding, used in the base of a fortified edifice.

TOWER, a building of great height in proportion to its horizontal dimensions, usually forming an adjunct to a larger building, and employed as a belfry, stronghold, watch, or beacon. Amongst the Romans, structures of this kind do not seem to have been very numerous; and when employed, they were not very lofty: they were of various forms. In the castles of the feudal ages, towers were very necessary; the keep usually consisted of a large square tower, with smaller ones at the angles, which were generally elevated above the central one. Sometimes, however, the keep is circular, and occasionally of irregular forms. Towers are also common at the entrances of other positions in fortifications. Churches are seldom found without an addition of this nature, either with or without a pyramidal spire. Church towers are sometimes detached from the main building, but most frequently adjoining; they are of various forms, designs, and proportions, and are found in every position, except at the east end of the chancel. Cathedrals and larger churches frequently have more than one tower, the most usual number being three, one at the intersection of nave and transept, and two others at the west end; sometimes the transepts are flanked with towers, as at Exeter. Smaller churches have only one tower which is variously situated, but as a rule, at the west end of nave, or in cruciform churches at the intersection. *See* Castle, Church, Cathedral, Gothic Architecture, and Round Tower.

TOWN, (from the Saxon, *tun*,) a collection of houses, walled round about for the defence of its inhabitants.

During the feudal system, when many inhabitants lived together, a wall surrounding their habitations was necessary, and now, though this system is abolished, and the surrounding walls have either gone to ruin, or have been taken down to extend the boundaries for habitation, the collection of houses still retains the name of *town*.

Town-Hall, a public hall in which the business of a town is transacted. It answers in some respects to the ancient basilica.

TRABS, (from the Latin *trabs*, a beam,) in ancient carpentry, those beams which are now called *wall-plates*, or *rising-plates*, for supporting the rafters.

TRACERY. That kind of pattern traced in the head of a Gothic window or panel by the divergence and intersection of the mullions.

The origin of this kind of work is to be observed in the works of the close of the 12th century, from which period it was gradually developed into its more perfect form. At a very early period it became customary to enclose two small arches within one larger one; and when this form came to be applied to windows, it must naturally have been observed that the tympanum, or blank space, contained between the larger arch and the heads of the smaller ones, offered a very favourable opportunity for increasing the lighting area by perforating it either wholly or partially: in fact, it appeared to form part of the window; and the idea of making it really so must readily have occurred to many persons; as a blank space, it is heavy, and rather offensive to the eye.

The first advance towards the development of tracery then occurred in this way; the tympanum was relieved by being pierced with an aperture in the form of a circle, quatrefoil, or some other simple figure, and sometimes the spandrels were treated in a similar manner. To this method of perforation the name of *plate*-tracery has been applied, while that in which the sides of the adjacent openings are always parallel, so that the patterns of the openings appear to be formed by the intersection of bars, is termed *bar*-tracery. This latter form arose, naturally enough, from the former, by the multiplication of the piercings, or apertures, till at last the plate disappeared, save what was just sufficient to separate the openings. Sometimes we find bar and plate tracery in the same window, which shows one stage in the development of the former.

At first, the bar-tracery was disposed in simple geometrical patterns, to which the name of *geometrical*-tracery has been given. This term, however, is scarcely appropriate, as all tracery is described geometrically, although not composed of the more common or regular geometrical figures, such as circles, squares, triangles, &c., of which the so-called geometrical tracery was mostly composed. The *flowing*-tracery is designed with greater freedom, and curve-lines of variable curvature are made to flow gracefully one into the other, branching off in various directions, and forming, in their progress, an infinite variety of patterns, the apertures so produced being, for the most part, in the shape of a leaf. Regular geometrical figures are sometimes found combined with the last system. As we near the Perpendicular period, the curves gradually become straight, the bars assume a vertical position, and are at last divided horizontally by transoms.

In all the above instances, the practice of cusping the various figures is very common, such ornamentation being

seldom omitted. When the tracery is of a complicated character, we find a sort of subordination observed amongst the less significant members; thus, the principal compartments of a window are divided by large bars, consisting of a large assemblage of mouldings, of which only a portion are employed in the bars which form the sub-divisions.

The Gothic buildings of France are noted for a peculiar form of tracery, termed *flamboyant*, from its flame-like appearance. It is similar to some examples of our flowing-tracery, but differs in this, that the leaf-like openings always terminate in a sharp point at the top, and thus assume rather the appearance of flames.

Tracery is employed, not only in windows, but also in screens, panels, &c., even when not pierced.

TRAIL, a running, or continuous, enrichment of leaves or flowers, with their tendrils or stalks, &c. Such enrichment is common in Gothic mouldings.

TRAMMEL, a rod of wood or metal, having sliding pieces, to which are affixed points, with which to describe large circles, or set off long distances.

TRANSEPT, that portion of a cruciform church which extends across the main body of the building, and usually separates the nave and choir. Thus, the nave and choir running from west to east, the transept will have its direction from north to south, and in the plan forms the shorter arms of the cross, projecting more or less beyond the nave and chancel aisles. Sometimes double transepts occur east and west of each other, as at Canterbury and Lincoln cathedrals; occasionally we find one at the extreme west, as at Ely; and also at extreme east, as at Durham and Peterborough. *See* Cathedral. Church.

TRANSITION, a term applied to certain classes of architectural examples, which appear to form a connecting link between two well-defined styles. It is especially applied to those buildings which are intermediate between the Norman, or Romanesque, and the Pointed styles. *See* Gothic Architecture.

TRANSOM, (from the Latin *transenna*, a cross beam,) in joinery, a horizontal piece, framed across a double-lighted window. When a window has no transom. it is called *a clear story window.*

Transom, a horizontal mullion, dividing a window into two stages in height. Transoms were not generally in use previous to the Perpendicular period of Gothic architecture, but are occasionally found in spire-lights of both Early English and Decorated buildings, where they seem to have been requisite for the purpose of strengthening. the window. They are also very common in domestic buildings of all periods, and in those of later date almost universal, the lights beneath being usually arched and cusped.

TRANSTRA, the horizontal timbers in the roof of Roman buildings.

TRANSVERSE, (from the Latin *trans*, over, and *verto versus*, to turn,) lying in a cross direction.

Transverse Strain, the strain against a piece of timber side-ways, by which it is more easily bent, or broken, than when compressed, as a straining-piece, or drawn in a direction of its length, as a tie.

TRANSYTE, a narrow or triforial passage.

TRAPEZIUM, (from τραπέζιον,) a plane figure with four unequal sides and angles. As every rectilinear figure may be divided into as many triangles, wanting two, as the figure has sides; a trapezium, which is a right-lined figure of four sides, may be divided into two triangles by a diagonal. Therefore, to find the superficial content, find the area of each triangle, and the sum of these areas is that of the trapezium.

TRAVELLING-CRANE, a very useful machine for hoisting materials in the erection of a building. It consists of a crab fixed on a carriage, which is movable upon rails to any part of a building where it may be required.

TRAVERSE, (from the Latin *traversus*,) to plane a board in a direction transverse to the fibres, in order to straighten it in that direction.

Traverse, a gallery or loft of communication, such as those found in large churches.

TREAD OF THE STEP OF A STAIR, the horizontal part of the step.

TREBEATION, the same as Entablature.

TREFOIL, an ornament much used in Gothic architecture, consisting of a figure of three cusps disposed within a circle, and enclosing a space similar in form to the three-leaved clover. Trefoils, however, are not invariably disposed within a circle; any cusped figure which encloses a tri-lobed space is termed a trefoil, even if it have only two cusps.

TRELLIS WORK, a reticulated framing, made of thin bars of wood, used in rural architecture. Any reticulated work.

TRESSEL, or Trussel. *See* Trussel.

TRIANGLE, (from the Latin *tres*, three, and *angulus*, a corner,) a plane figure of three sides, and consequently as many angles. In measuring, all rectilinear figures must be reduced to triangles; and in constructions for carpentry, all frames of more than three sides must be reduced to triangles, to prevent a revolution round the angles.

TRIANGULAR COMPASSES, such compasses as have three legs, or feet, by which any triangle, or three points, may be taken off at once. *See* Instruments.

TRICLINIUM, a hall, or apartment. used by the ancients. *See* Cyzicene.

TRIFORIUM, the gallery contained in the space between the vault and timber-roof of the aisles of a church; presenting towards the interior a continuous arcade, situate between the lower arcade and the clere-story.

TRIGLYPHS, (from τρεῖς, *three*, and γλυφάς, *a channel*, or *furrow*,) the tablets in the Doric frieze, chamfered on the two vertical edges, and with two channels in the middle called glyphs, or carvings. In the Grecian Doric, the triglyph is placed upon the angle; but in the Roman, the triglyph next the angle is over the centre of the column.

TRIGONOMETRY, (from τρεῖς, *three*, γονια, *a corner* and μετρεω, *to measure*) the art of measuring the unknown parts of a triangle, from the remaining parts being given.

Trigonometry, is either *Plane*, or *Spherical*. *Plane* trigonometry is the arts of measuring the unknown parts of a plane rectilinear triangle. This, on many occasions, might be of considerable use to the architect and engineer, in ascertaining certain distances and dimensions, which might otherwise be very inconvenient to obtain. Indeed, it is founded upon such obvious principles, that when once understood it can never be forgotten.

Every triangle consists of six parts, *viz.* the three sides and the three angles: any three of these six parts, except the three angles, being given, the rest may be ascertained.

Definitions.

Definition 1.—The chord of an arc is a straight line, A B, joining its two extremities.

Definition 2.—The sine of an arc is a straight line, B C, drawn from one extremity perpendicular to the diameter drawn through the other extremity of the arc, A B.

Corollary.— Hence, the sine of an arc is the same as the

sine of its supplement; the supplement being an arc of such dimensions as will, together with the original arc, make an arc of 180°, or, in other words, a semicircle: thus, an arc of 120° is the supplement of an arc of 60°, and *vice versa*, because 60° + 120° = 180°. Similarly, the complement of an arc is an arc of such dimensions as, together with the original arc, to make an arc of 90°; thus, an arc of 50° is the complement of an arc of 40°, and *vice versa*.

Definition 3.—The tangent of an arc is a straight line, A D, drawn from one extremity of the radius, A C, perpendicular to the same, A C, terminated at the other extremity by a continued radius drawn through the other extremity, B, of the arc A B.

Definition 4.—The secant of an arc is a straight line, D C, passing through one extremity of the arc and the centre, and terminated by the tangent, which passes through the other extremity.

The versed sine is that part of the radius which is intercepted between the foot of the sine and the beginning of the arc.

The co-tangent and co-secant are respectively the tangent and secant of the complement.

Definition 5.—The sine, tangent, or secant of an angle, is the same as that of the arc intercepted.

As trigonometry is chiefly performed by proportion, and as all proportion consists of multiplication or division, or both, and since multiplication and division is best performed by logarithms, we shall here give a short sketch of the nature and construction of logarithms.

The sum of the logarithms of any two numbers, x and z, is the logarithm of their product. Let x be the logarithm of x, and z the logarithm of z; then taking the exponents of the power of a constant root for the logarithm, we have $x = a^{x}$, and $z = a^{z}$. Therefore $x\,z = a^{x}\,a^{z} = a^{x+z}$; therefore x + z is the logarithm of $x\,z$; that is the sum of the logarithms of any two numbers is the logarithm of their product.

Corollary.—Hence, if $x = z$ the logarithms of x^2 is 2 x or of $z^2 = 2$ z.

In the same manner the logarithm $x\,y\,z$ will be found to be x + y + z, and consequently the logarithm of $x^3 = 3$ x; therefore, universally, the logarithm of a power is the logarithm of the root multiplied by the index of the power.

The difference of the logarithms of any two numbers, x and z, is equal to the logarithm of their quotient; since $x = a^{x}$ and $z = a^{z}$, therefore $\frac{x}{z} = \frac{a^{x}}{a^{z}} = a^{x-z}$; therefore, x—z is the logarithm of $\frac{x}{z}$.

The logarithm of the nth root of any number, x, is the logarithm of that number divided by n.

Since $x = a^{x}$; by taking the nth root of both sides, we have $x^{\frac{1}{n}} = a^{\frac{x}{n}}$; but $\frac{x}{n}$ is the logarithm of x^n. And in the same manner we find the logarithm of the nth power of any number, x, is n times the logarithm of that number, for $x = a^{x}$; raise both sides to the nth power, then will $x^n = a^{nx}$; therefore n x is the logarithm of x^n.

To determine two such functions of two quantities, $x + 1$ and $z + 1$, so that if the same operation be separately performed upon $x + 1$ and $z + 1$, and upon their product, the sum of the functions of $x + 1$ and $z + 1$, may be equal to the function of their product:

I. That is, $\phi(x+1) + \phi(z+1) = \phi[(x+1)(z+1)] = \phi(1 + x + z + x\,z)$.

II. Assume $\phi(1+x) = a + b\,x + c\,x^2 + d\,x^3 +$, &c.

III. Therefore, $\phi(1+z) = a + b\,z + c\,z^2 + d\,z^3 +$, &c. And by the same operation we obtain,

IV. $\phi[1 + (x + z + x\,z)] = a + \begin{matrix} b\,x \\ b\,z \end{matrix} + (b + 2\,c) \begin{matrix} c\,x^2 \\ x\,z + \\ c\,z^2 \end{matrix} + (2\,c + 3\,d) \begin{matrix} d\,x^3 \\ x^2 z + \\ x\,z^2 \end{matrix}$, &c.

and by adding No. II. and No. III. together, we obtain,

V. $\phi(1+x) + \phi(1+z) = 2\,a + \begin{matrix} b\,x \\ b\,z \end{matrix} + \begin{matrix} c\,x^2 \\ c\,z^2 \end{matrix} - \begin{matrix} d\,x^3 \\ d\,z^3 \end{matrix} +$, &c.

Then comparing the co-efficients of IV. and V. we obtain,

$a = o, b = b, c = -\frac{b}{2}, d = \frac{b}{3}, e = -\frac{b}{4}$, &c., whence we obtain,

VI. $\phi(1+z) = b\,(z - \frac{z^2}{2} + \frac{z^3}{3} - \frac{z^4}{4} +$ &c.,) which is the logarithm of $1 + z$.

Let M = b, substitute $-z$ for x, in the series VI. and we obtain,

VII. L'$(1-z)$ = M $(-z - \frac{z^2}{2} - \frac{z^3}{3} - \frac{z^4}{4} -$, &c.)

Subtract No. VII. from No. VI. and we obtain,

VIII. L'$(1+z)$ − L'$(1-z)$ = 2M $(z^1 + \frac{z^3}{3} + \frac{z^5}{5} + \frac{z^7}{7} +$, &c.,) or,

IX. $\text{L}' \frac{1+z}{1-z} = 2\,\text{M}\,(z + \frac{z^3}{3} + \frac{z^5}{5} + \frac{z^7}{7} +, \&c.)$

In VI. substitute $\frac{x}{x}$ for z, and we obtain,

X. $\text{L}' \frac{x+x}{x} = \text{M}\left(\frac{x}{x} - \frac{x^2}{2x^2} + \frac{x^3}{3x^3} - \frac{x^4}{4x^4} +, \&c.\right)$ or,

XI. $\text{L}'(x+x) - \text{L}'x = \text{M}\left(\frac{x}{x} = \frac{x^2}{2x^2} + \frac{x^3}{3x^3} - \frac{x^4}{4x^4} +, \&c.,\right)$ and, by transposition, we obtain,

XII. $\text{L}'(x+x) = \text{L}'x + \text{M}\left(\frac{x}{x} - \frac{x^2}{2x^2} + \frac{x^3}{3x^3} -, \&c.\right)$

In IX. substitute $\frac{x}{x}$ for z, and we obtain,

$$\text{L}' \frac{x+x}{x-x}\ 2\,\text{M}\left(\frac{x}{x} + \frac{x^3}{3x^3} + \frac{x^5}{5x^5} + \frac{x^7}{7x^7} +, \&c.\right)$$

In IX. for z substitute $\frac{v-1}{v+1}$, and we obtain,

XIII. $\text{L}'v = 2\,\text{M}\left(\frac{v-1}{v+1} + \frac{(v-3)^3}{3\,(v+1)^3} + \frac{(v-1)^5}{5\,(v+1)^5} + \frac{(v-1)^7}{7\,(v+1)^7} +, \&c.\right)$

This series will always converge, whatever be the value of v; but as v is greater, the degree of convergency becomes less, and, therefore, the logarithms of small numbers may be easily found; but, in the computation of large numbers, the calculation would extend to too great a length to be of any practical utility. In order, therefore, to save trouble, it becomes necessary to derive the logarithm of one number from that of another.

In XIII. for v substitute $v + 1$, and we obtain,

XIV. $\text{L}'(1+v) = 2\,\text{M}\left(\frac{v}{1\,(v+2)} + \frac{v^3}{3\,(v+2)^3} + \frac{v^5}{5\,(v+2)^5} +, \&c.\right)$

In IX. substitute $\frac{x}{2-x}$ for z, and we obtain,

XV. $\text{L}' \frac{1}{1-x} = 2\,\text{M}\left(\frac{x}{2-x} + \frac{x^3}{3\,(2-x)^3} + \frac{x^5}{5\,(2-x)^5} +, \&c.\right)$

In XIII. let $v = \frac{z+z}{z}$, and we obtain,

XVI. $\frac{z+z}{z} = 2\,\text{M}\left(\frac{z}{1\,(2z+z)} + \frac{z^3}{3\,(2z+z)^3} + \frac{z^5}{5\,(2z+z)^5} +, \&c.,\right)$ therefore,

XVII. $\text{L}'(z+z) - \text{L}z = 2\,\text{M}\left(\frac{z}{(2z+z)} + \frac{z}{3\,(2z+z^3)} +, \&c.\right)$ therefore,

XVIII. $\text{L}'(z+z) = \text{L}'z + 2\,\text{M}\left(\frac{z}{(2z+z)} + \frac{z^3}{3\,(2z+z)^3} +, \&c.\right)$

PRACTICAL EXAMPLE.

The logarithm of 18 being 1.255273, to find the logarithm 19 by the series XX.

Here $z = 18, z = 1$;

therefore, $\text{L}'19 = \text{L}\,18 + 2\,\text{M}\left(\frac{1}{37} + \frac{1}{3\,(37)^3} + \frac{1}{5\,(37)^5} +, \&c.\right)$

$= \text{L}'19 + 2 \times .4342945\left(\frac{1}{37} + \frac{1}{3\,(37)^3} + \frac{1}{5\,(37)^5} +, \&c.\right)$

$2 \times .4342945 = .868589 \qquad (37)^2 - 1369$

	(1369)	(	3)
87) 868589	(.023475	(.	17
74	1369		
			5
128	9785		
111	9583		
175	202		
148			
278			
259			
199			
185			
14			
.023475			
5			
.023480 sum			
add 1.255273 the log. 18.			
the sum 1.278753 is the logarithm of 19.			

To find the logarithm of 2 from *Series* XIX. Here $z=1$ and $z=1$, and by substituting the numbers, the series becomes

$$\text{Log. } 2 = 0 + .86858896\left(\frac{1}{3} + \frac{1}{3.3^3} + \frac{1}{5.3} + \frac{1}{7.3^7} + \&c.\right)$$

work, therefore, as follows:

3) .86858896			
9) .28952965	÷	1 =	.28952965
9) 3216996	÷	3 =	.1072332
9) 357444	÷	5 =	71488
9) 39716	÷	7 =	5673
9) 4412	÷	9 =	490
9) 490	÷	11 =	44
54	÷	13 =	4
			.30102996

which is the logarithm of 2 nearly. By only adding .00000004, we should have .30103, which is the number to be found in the common tables of logarithms. And lastly, by reverting the series,

$$\text{L}'(1+x) = \text{M}\left(x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \&c.\right)$$

we obtain

$$x = 1 + \text{A}x + \frac{\text{A}^2x^2}{1.2} + \frac{\text{A}^3x^3}{1.2.3} + \frac{\text{A}^4x^4}{1.2.3.4} + \&c.,$$

which is the value of the number x when the logarithm of x is given. Here $\text{A} = \frac{1}{\text{M}}$.

Trigonometrical Formulæ.

The circumference of a circle being divided into 360 degrees, of which 90° forms a right angle, affords us a ready means of connecting angular space with lines, for the dimensions of an angle will vary directly as the arc, and inversely as the radius. Thus if we make the sides containing any angle of equal length, and measure the width of the opening, as also the length of either side, we shall be able to find the number of degrees contained by the angle. Now we know with sufficient accuracy for all practical purposes, the number of times which a radius is contained in its circumference, which is 2×3.14159, &c.; and by this proportion, we shall be enabled to find our angle.

For instance, suppose the width of the opening to measure 52.359 feet, and the length of the side 100 feet, then $100 \times 3.14159 = 314.159$ gives the length of the semi-circumference, or an arc of 180°. Then $\frac{314.159}{52.359} = 6$ gives the number of times which the arc to be found, is contained in an arc of 180°; therefore $\frac{180°}{6} = 30°$ is the measure of the angle required.

The following Table gives the value of the sine, cosine, &c. in terms of each other, so that if one be given, the other may be found.

Sin.	$\text{A} =$	$\sqrt{1 - \cos.^2\text{A}}$;
Cos.	$\text{A} =$	$\sqrt{1 - \sin.^2\text{A}}$;
Vsin.	$\text{A} =$	$1 - \cos.\text{A}$;
Tan.	$\text{A} =$	$\frac{\sin.\text{A}}{\cos.\text{A}}$;
Cot.	$\text{A} =$	$\frac{\cos.\text{A}}{\sin.\text{A}} = \frac{1}{\tan.\text{A}}$;
Sec.	$\text{A} =$	$\frac{1}{\cos.\text{A}} = \sqrt{1 + \tan.^2\text{A}}$
Cosec.	$\text{A} =$	$\frac{1}{\sin.\text{A}} = \sqrt{1 + \cot.^2\text{A}}$

The following numerical values of the sine, cosine, tangent, and secant, of 30° 45° 60° 120° are of frequent use. They are calculated to radius = 1.

30°.

The chord of $60° = 2 \sin. 30°$
But chord of $60° =$ rad. $= 1$.
$\therefore \sin 30 = \frac{1}{2}$.

$$\text{Cos. } 30 = \sqrt{1 - \sin.^2 30} = \sqrt{1 - \frac{1}{4}} = \frac{\sqrt{3}}{2}.$$

$$\text{Tan. } 30 = \frac{\sin. 30}{\cos. 30} = \frac{\frac{1}{2}}{\frac{\sqrt{3}}{2}} = \frac{1}{\sqrt{3}}.$$

$$\text{Sec. } 30 = \frac{1}{\cos. 30} = \frac{1}{\frac{\sqrt{3}}{2}} = \frac{2}{\sqrt{3}}.$$

45°

Since sine of an arc = cosine of its compliment;

$\therefore \sin. 45 = \cos. \overline{90 - 45} = \cos. 45.$
But $\sin.^2 45 + \cos.^2 45 = 1$;

$\therefore 2 \sin.^2 45 = 1$; or $\sin. 45 = \frac{1}{\sqrt{2}} = \cos. 45.$

$$\text{Tan. } 45 = \frac{\sin. 45}{\cos. 45} = \frac{\sin. 45}{\sin. 45} = 1$$

$$\text{Sec. } 45 = \frac{1}{\text{cos. } 45} = \frac{1)}{\frac{1}{\sqrt{2}}} = \sqrt{2}.$$

60°

$$\text{Sin. } 60 = \cos. \overline{90 - 60} = \text{cos. } 30 = \frac{\sqrt{3}}{2}.$$

$$\text{Cos. } 60 = \text{sin. } \overline{90 - 60} = \text{sin. } 30 = \frac{1}{2}.$$

$$\text{Tan. } 60 = \frac{\text{sin. } 60}{\text{cos. } 60} = \frac{\frac{\sqrt{3}}{2}}{\frac{1}{2}} = \sqrt{3}.$$

$$\text{Sec. } 60 = \frac{1}{\text{cos. } 60} = \frac{1}{\frac{1}{2}} = 2.$$

120°

Since the sine of an arc = sine of its supplement, and the cosine of an arc = — cosine of its supplement;

$$\text{Sin. } 120 = \text{sin. } 60 = \frac{\sqrt{3}}{2}.$$

$$\text{Cos. } 120 = \text{cos. } 60 = -\frac{1}{2}.$$

$$\text{Tan. } 120 = \frac{\text{sin. } 120}{\text{cos. } 120} = \frac{\frac{\sqrt{3}}{2}}{-\frac{1}{2}} = -\sqrt{3}.$$

$$\text{Sec. } 120 = \frac{1}{\text{cos. } 120} = \frac{\cdot 1}{-\frac{1}{2}} = -2.$$

The above, as we observed, are calculated for a circle whose radius = 1, but if we require their value in a circle of any other radius, it can be readily obtained, for we have this rule to transform formulas, computed to a radius unity, into others computed to a radius (r); write, for sin. A, cos. A., &c. $\frac{\text{sin. A}}{r}$, $\frac{\text{cos. A}}{r}$ &c., and the values of the sin. A, and cos. A, &c. so found, will be in terms of the radius (r).

Also if we know the numerical values of sin. A, and cos. A, to radius unity, and we wish to have them to a radius (r), we must multiply the numerical value by (r);

For $\frac{pn}{r}$ = sin. A; $\therefore pn = r$ sin. A

or sin A° to radius $r = r \times$ sin. A to rad. = 1.

Ex. Find the numerical value of sin. 30 to rad. 10.000.

$$\text{sin. 30 to rad. unity} = \frac{1}{2} = .5;$$

$\therefore$ sin. 30 to rad. $10.0000 = 10.000 \times .5 = 5000.$

We may here observe, that in any right-angled triangle, the sine of one of the acute angles $= \frac{\text{altitude}}{\text{hypothenuse}}$, the cosine $= \frac{\text{base}}{\text{hypothenuse}}$ and the tangent $= \frac{\text{altitude}}{\text{base}}$.

The sine and cosine of any two unequal arcs of the same circle being given; to find the sine of any multiple of the lesser arc.

Let EK be any arc of a circle, which being divided into two arcs, EF the less and FK the greater, draw the radii EC, FC, and KC; make FD equal to FE, and join DE cutting CT at L: draw EM, LO, FG, and DH, perpendicular to CK, cutting CK in M, O, G, and H: parallel to CK draw DS, cutting LO at S, and LN cutting EM at N: then let r = CE = CF = CK, let the arc FK be called B, and the arc EF be called A; then FG is the sine of B, CL the cosine of A, CG cosine of B, and EL the sine of A: then, by similar triangles,

CF : FG :: CL : LO, that is,

$$r : \text{sin' B} :: \text{cos' A} : \text{LO} = \frac{\text{sin' B} \times \text{cos' A}}{r}$$

Again, by similar triangles,

CF : CG :: EL : EN, that is,

$$r : \text{cos' B} :: \text{sin' A} : \text{EN} = \frac{\text{cos' B} \times \text{sin' A}}{r}$$

Now EM = sin' (A + B) = NM + EN = LO + EN; therefore, by addition,

$$\text{sin' (B + A)} = \frac{\text{sin' B} \times \text{cos' A} + \text{cos' B} \times \text{sin' A}}{r}$$

Again, DH = sin' (B — A) = LO — EN; therefore, by subtraction,

$$\text{sin' (B — A)} = \frac{\text{sin' B} \times \text{cos' A} - \text{cos' B} \times \text{sin' A}}{r}.$$

These formulæ may be simplified by putting $r = 1$, thus:

Form. 1. sin' (B + A) = sin' B × cos' A + cos' B × sin' A.

Form. 2. sin' (B — A) = sin' B × cos' A — cos' B × sin' A; add these formulæ together, and we obtain,

Form. 3. sin' (B + A) + sin' (B — A) = 2 × sin' B × cos' A; therefore, sin' (B + A) = 2 × cos' A + sin' B — sin' (B — A).

Let B = $(n - 1)$ A; then will

sin' n A = 2 × cos' A × sin' $(n - 1)$ A — sin' $(n - 2)$ A, which is a general theorem.

Now in this general theorem, let n be put successively equal to 1, 2, 3, 4, &c., and we obtain,

s' 1 A = s' A.
s' 2 A = 2 × c' A × s' A.
s' 3 A = 2 × c' A × s' 2 A — s' A.
s' 4 A = 2 × c' A × s' 3 A — s' 2 A.
s' 5 A = 2 × c' A × s' 4 A — s' 3 A, &c.

where s' signifies the sine of the quantity that follows, and c' the cosine of the quantity that follows it.

In the last article, put 2 A = a; $\therefore$ A = $\frac{a}{2}$.

$$\therefore \text{sin. } a = 2 \text{ sin.} \frac{a}{2} \cdot \text{cos.} \frac{a}{2};$$

$$\text{and cos. } a = 1 - 2 \text{ sin.}^2 \frac{a}{2} = 2 \text{ cos.}^2 \frac{a}{2} - 1,$$

by which formulas we find the sine and cosine of an arc in terms of the sine and cosine of half the arc.

A great variety of formulas may be deduced from the general formulas; the following are the most important:

Adding 1 and 2 together—

sin. (A + B) + sin. (A — B) = 2 sin. A cos. B.

And similarly, also, we have—

cos. (A + B) + cos. (A — B) = 2 cos. A cos. B,
sin. (A + B) — sin. (A — B) = 2 sin. B cos. A,
cos. (A — B) — cos. (A + B) = 2 sin. A sin. B.

Let $A+B=m$, and $(A-B)=n$;

$$\therefore A=\frac{m+n}{2} \text{ and } B=\frac{m-n}{2}, \text{ and}$$

$$\sin. m+\sin. n=2\sin.\frac{m+n}{2}.\cos.\frac{m-n}{2}$$

$$\cos. m+\cos. n=2\cos.\frac{m+n}{2}.\cos.\frac{m-n}{2}$$

$$\sin. m-\sin. n=2\sin.\frac{m-n}{2}.\cos.\frac{m+n}{2}$$

$$\cos. n-\cos. m=2\sin.\frac{m+n}{2}.\sin.\frac{m-n}{2}.$$

Again—

since $\sin.(A+B)=\sin. A\cos. B+\sin. B\cos. A$

and $\sin.(A-B)=\sin. A\cos. B-\sin. B\cos. A$

therefore,

$$\sin.(A+)\sin.(A-B)=\sin.^2A\cos.^2B-\sin.^2B\cos.^2A$$
$$=\sin.^2A(1-\sin.^2B)-\sin.^2B(1-\sin.^2A)$$
$$=\sin.^2A-\sin.^2B$$
$$=(\sin. A+\sin. B)(\sin. A-\sin. B)$$

$$\cos.(A+B)=\cos. A\cos. B-\sin. A\sin. B$$

$$\cos.(A-B)=\cos. A\cos. B+\sin. A\sin. B$$

$$\cos.(A+B)\cos.(A-B)=\cos.^2A\cos.^2B-\sin.^2A\sin.^2B$$
$$=\cos.^2A(1-\sin.^2B)-(1-\cos.^2A)\sin.^2B$$
$$=\cos.^2A-\sin.^2B=(\cos. A+\sin. B)\times(\cos. A-\sin. B).$$

Again—

$$\sin.(A+B)=2\sin. A\cos. B-\sin.\overline{A-B}$$
$$\cos. A+B=2\cos. A\cos. B-\cos. A-B$$

Hence, if we have three arcs, $A+B$, A, and $A-B$, given in arithmetic progression, the sine and cosine of $A+B$ may be found from the sines and cosines of A and $A-B$. Thus, to find $\sin. A+B$, multiply $\sin. A$ by $2\cos. B$, and $\sin. A-B$ by (-1), the sum of the products will be $\sin. A+B$; and to find $\cos. A+B$, multiply $\cos. A$ by $2\cos. B$, and $\cos. A-B$ by (-1), and add the results together. The expression $2\cos. B-1$, is called the scale of relation; and $\sin. A+B$, $\sin. A$, and $\sin. A-B$ are called terms of a recurring series.

Since $\sin.(A+B)+\sin.(A-B)=2\sin. A\cos. B$,
and $\cos.(A+B)+\cos.(A-B)=2\cos. A\cos. B$.

For B put a, and for A put na;

$$\therefore A+B=na+a=\overline{n+1}.a$$
$$A-B=na-a=n-1.a;$$
$$\therefore \sin.(n+1)a+\sin.(n-1)a=2\sin. na\cos. a$$
$$\text{and } \cos. n+1\ a+\cos.(n-1)a=2\cos. na\cos. a.$$

Let $n=2$; $\therefore n+1=3$, and $n-1=1$

Therefore,

$$\sin. 3a+\sin. a=2\sin. 2a\times\cos. a=2(2\sin. a\cos. a)\cos. a$$
$$=4\sin. a\cos.^2a=4\sin. a(1-\sin.^2a)$$
$$=4\sin. a-4\sin.^3a;$$
$$\therefore \sin. 3a=3\sin. a-4\sin.^3a$$
$$\text{and } \cos. 3a+\cos. a=2\cos. 2a\cos. a.$$
$$=2(2\cos.^2a-1)\cos. a.$$
$$=4\cos.^3a-2\cos. a.$$
$$\therefore \cos. 3a=4\cos.^3a-3\cos. a.$$

These formulas for $\sin. 3a$, and $\cos. 3a$, give the values of the sine and cosine of triple the arc in terms of the sine and cosine of the simple arc.

To find the sine and cosine of an arc in terms of the sine of twice the arc.

$$\text{Cos.}^2A+\sin.^2A=1$$
$$2\sin. A.\cos. A=\sin. 2A;$$
$$\therefore \cos.^2A+2\sin. A\cos. A+\sin.^2A=1+\sin. 2A;$$
$$\text{and } \cos.^2A-2\sin. A\cos. A+\sin.^2A=1-\sin. 2A.$$

$$\therefore \cos. A+\sin. A=\pm\sqrt{1+\sin. 2A}$$
$$\cos. A-\sin. A=\pm\sqrt{1-\sin. 2A}$$

$$\therefore \cos. A=\tfrac{1}{2}\left\{\sqrt{1+\sin. 2A}\pm\sqrt{1-\sin. 2A}\right\}$$
$$\sin. A=\tfrac{1}{2}\left\{\sqrt{1+\sin. 2A}\pm\sqrt{1-\sin. 2A}\right\}$$

When A is $<45°$, $\cos. A$ is $>\sin. A$, and we must use the upper signs; but when $A>45°$, $\sin. A$ is $>\cos. A$, and we must use the lower signs.

These values for $\cos. A$ and $\sin. A$ are termed formulas of verification; for, by means of them, we are enabled to test or verify the accuracy of results obtained by other processes.

Thus, to find $\sin. 15°$,

$$\text{Sin. } 15=\sin.(45-30)=\sin. 45\cos. 30-\sin. 30\cos. 45$$
$$=\frac{\sqrt{3}}{2\sqrt{2}}-\frac{1}{2\sqrt{2}}=\frac{\sqrt{3}-1}{2\sqrt{2}}$$

Then, in the formula, let $A=15$;

$$\therefore 2A=30 \text{ and } \sin. 2A=\frac{1}{2} \text{ and } \overline{1+\sin. 2A}=\frac{3}{2}, \overline{1-\sin. 2A}=\frac{1}{2};$$

$$\therefore \sin. 15=\frac{1}{2}\left(\sqrt{\frac{3}{2}}-\sqrt{\frac{1}{2}}\right)=\frac{\sqrt{3}-1}{2\sqrt{2}},$$ the same result as before.

The utility of the preceding formulas may be shown in finding the numerical values of some arcs.

$$\text{Sin. } (45+A)=\sin. 45\cos. A+\sin. A\cos. 45$$
$$=\frac{1}{\sqrt{2}}(\cos. A+\sin. A).$$
$$\text{Cos. } (45+A)=\cos. 45\cos. A-\sin. 45\sin. A$$
$$=\frac{1}{\sqrt{2}}(\cos. A-\sin. A).$$

Let $A=30$; $\therefore \cos. A=\frac{\sqrt{3}}{2}$, and $\sin. A=\frac{1}{2}$;

$$\therefore \sin. 75=\frac{\sqrt{3}+1}{2\sqrt{2}} \text{ and } \cos. 75=\frac{\sqrt{3}-1}{2\sqrt{2}}.$$

Next let $A=90$; $\therefore \cos. A=0$, and $\sin. A=1$

$$\therefore \sin. 135=\frac{1}{\sqrt{2}}, \text{ and } \cos. 135=-\frac{1}{\sqrt{2}}.$$

To find the sine and cosine of $18°$ and $36°$

$$5\times 18°=90°;\ \therefore 3\times 18°=90°-2\times 18°$$
$$\therefore \cos.(3\times 18°)=\cos.(90°-2\times 18°)=\sin. \overline{2\times 18°}$$

But $\cos. \overline{3\times 18}=4\cos.^318-3\cos. 18$,

$$\text{Sin. } \overline{2\times 18}=2\sin. 18\cos. 18;$$
$$\therefore 4\cos.^318-3\cos. 18=2\sin. 18\cos. 18.$$

Let $8=x$;

$$\therefore 4(1-x^2)-3=2x, \text{ or } 4x^2+2x=1$$
$$\therefore x^2+\frac{x}{2}+\frac{1}{16}=\frac{1}{4}+\frac{1}{16}=\frac{5}{16}$$
$$\therefore x=\frac{\sqrt{5}-1}{4}=\sin. 18=\cos. 72.$$

But,

$$4(1-x^2) = 4\cos.^2 18 = 2x + 3 = \frac{\sqrt{5}-1}{2} + 3 = \frac{5+\sqrt{5}}{2}$$

$$\sqrt{1-x^2} = \cos. 18 = \frac{\sqrt{5+\sqrt{5}}}{2\sqrt{2}}$$

THEOREMS. (*The figures, as marked on the Plate, are according to the numbers of the Theorems.*)

Theorem 1.—*The sides of any plane triangle are as the sines of the angles opposite to them.*

Figure 1.—Let A B C be a triangle; upon B C let fall the perpendicular A D: from B A and C A take B E and C H, equal to each other; on B, with the radius B E, describe the arc E F, cutting B C at F; on C, with the radius C H, describe the arc H I cutting B C at I; draw E G and H K parallel to A D, cutting B C at G and K; then will E G be the sine of the arc E F, or of the angle E B F; and H K will be the sine of the arc H I, or of the angle H C I: now, let B E and C H be called radius, denoted by R, and let E G be called the sine of angle B, and H K the sine of angle C; then, by similar triangles,

B A : A D : : B E or C H : E G.

Again, by similar triangles,

A D : A C : : H K : H C or B E;

therefore,

B A : A C : : H K : E G;

that is,

B A : A C : : sin' C : sin' B.

Therefore, the sides of triangles are as the sines of their opposite angles.

Theorem 2.—*In any plane triangle, as the sum of the two sides is to their difference, so is the tangent of half the sum of the opposite angles to the tangent of half their difference.*

Figure 2.—Let A B C be a plane triangle; from B C cut off B D equal to B A, and join A D; bisect the angle A B C by the straight line B E; then will B E also bisect A D; let F be the point of section, and let B E meet A C in E; through F draw F G parallel to A C, cutting B C in G; then by similar triangles, B C E and B G F,

B G : G C : : B F : F E.

But D C is the difference of the sides B A and B C; and because D F : F A : : D G : G C; but D F and F A are equal, whence D G and G C are equal; therefore, D G or G C, is half the difference of the sides; now half the difference of the sides, added to the lesser side, is half the sum of the sides. It is evident, that B A D is half the sum of the angles C A B and B C A, and D A C is half their difference; now, by considering A F as radius, B F will be the tangent of the angle B A F, or B A D, and F E the tangent of the angle F A E, or D A C; therefore, as B G, half the sum of the two sides, is to G C, half their difference, so is B F, the tangent of the half sum of the opposite angles, to F E, the tangent of half their difference; and, consequently, as the sum of the two sides is to their difference, so is the tangent of the half sum of the opposite angles, to the tangent of half their difference.

Theorem 3.—*In any plane triangle, if a perpendicular be let fall upon the longest side from the opposite angle; then, as the sum of the segments of the longest side, or base, is to the sum of the other two sides, so is the difference of the sides to the difference of the segments of the base.*

Figure 3.—In the triangle A B C, left fall the perpendicular A E upon B C; about A as a centre with the distance, A C, of the shortest side, describe a circle: produce B A to meet the circumference in G; then will B G be the sum of the two sides, and B F their difference; also, B E and E C are the segments of the base, and B D their difference; now, by the property of the circle, B G × B F = B C × B D;

whence, B C : B G : : B F : B D;

that is, as the longest side, B C, is to B G, the sum of the other two sides, so is B F the difference of the sides, to B D, the difference of the segments of the base.

When two angles of a triangle are given, the third angle is found by subtracting the sum of the two given angles from 180°, or two right angles; and, consequently, if one of the acute angles of a right-angled triangle be given, the remaining angle will be found, by subtracting the acute angle from 90; for, in this case also, two angles are given, *viz.*, one of the acute angles and the right angle; and these being subtracted from two right angles, or 180, the other acute angle will be found.

Various propositions might be given, but the preceding are sufficient for every case of plane trigonometry.

The analogies of plane trigonometry may easily be deduced from those of spherical trigonometry; the former being particular cases of the latter.

Proposition.—The sum, s, and difference, d, of two quantities, x and y, being given; to find the quantities themselves.

Let $x + y = s$

$x - y = d$

add these equations together, and $2x = s + d$ or $x = \frac{s+d}{2}$;

subtract these equations from each other, and $2y = s - d$, or $y = \frac{s-d}{2}$; whence x, the greater of the two quantities, is half the sum and difference of these quantities; and y, the lesser, is half of the difference between the sum and difference; or, in other words, the half sum added to the half difference, gives the greater quantity; and the half sum subtracted from the half difference, gives the lesser quantity.

Solutions of the three cases of oblique-angled triangles.

Every plane triangle consists of six parts, the three sides and the three angles; three of these parts must always be given, and of these given parts one at least must be a side; to find the remaining three parts.

Case 1.—*Two angles and a side being given, to find the remaining sides.*

As the sine of the angle opposite the given side is to the sine of the angle opposite the required side, so is the given side to the required side.

In the oblique-angled triangle, A B C, given the angle A 59°, the angle C 52° 15′, and the side A B 276.5, to find A C and B C.

We shall find

angle B = 180° − (52° 15′ + 59°) = 68° .45,

as the sine < C 52° 15′	9.89801
is to sine of < B 68° 45′	9.96942
so is the side A B 276.5	2.44170
	12.41112
to the side A C 325.9	2.51311

To find B C.

As the sine of < C 52° 15′	9.89801
is to the sine of < A 59°	9.93307
so is A B 276.5	2.44170
	12.37477
to B C 299.8	2.47676

GEOMETRICAL CONSTRUCTION.

From a scale of equal parts draw A B = 276.5, and by the protractor, or line of chords, make angle A 59°. Now the triangle cannot be constructed without having the angle B;

therefore subtract the sum of angles A and C from 180° which gives angle B, that is 180—(59°+52° 15′) or 180—111° 15′ = 68.45 = angle B; make angle B 68° 45′, then A C and B C being measured by the same scale as A B, will give their respective lengths.

Case 2.—Two sides, and an angle opposite to one of them, being given; to find the other two angles and the remaining side.

As the side opposite the given angle
is to the side opposite the required angle
so is the given angle
to the required angle.

Example.—In the oblique-angled triangle A B C, obtuse at B, given A C 318 yards, B C 195 yards, and the angle A 32° 40′, to find the angles B and C, and the side A B.

Construction.—Draw A C = 318 from a scale of equal parts; make angle A = 32° 40′; with the distance 195 equal parts and the centre C describe an arc cutting A B at B, and join B C; the angles B and C will be found by the protractor, or line of chords, and the side A B by the same scale from which the other two sides were taken.

By Calculation.

As the side B C, 195	2.290035
is to the side A C, 318	2.502427
so is the sine′ A, 32° 40′	9.732193
	12.234620
to the sine of B, 61° 40′	9.944585

But since the tables give only acute angles, and the angle required is obtuse, and the sine of any angle is the same as the sine of its supplement,
therefore 180—61° 40′ = 118° 20′ = angle B.

Note.—When the given side opposite to the given angle is greater than the other given side, the angle opposite to such other given side, or the angle to be first found, is always acute, and is found by proportion; but when the side opposite to the given angle is less than the other given side, the opposite angle may either be acute or obtuse.

To find the side A B.

As the sine of A 32° 40′	9.732193
is to the sine of C 29°	9.685571
so is B C 195	2.290035
	11.975606
to A B 175.15	2.243413

Case 3.—Given the two sides and the included angle; to find the other two angles, and the third side.

As the sum of the two sides
is to their difference,
so is the tangent of half the sum of the opposite angles
to the tangent of half their difference.

Having by this proportion found the difference of the angles of the base, then half of the sum added to the half difference, gives the greater angle, and half of the sum diminished by the half difference gives the lesser angle.

Example.—For the triangle A B C, given the side A C 919.95, the side A B 500 feet, and the contained angle A 36° 52′; to find the angles B and C, and the side B C.

Construction.—Make the angle B A C = 36° 52′; make A B = 500 from a scale of equal parts, which set from A to B; from the same scale transfer 919.95 from A to C, and join A C; then the side A C will be found upon the line of equal parts, and the angles B and C by the protractor, or line of chords.

By calculation, to find the angles.

Now 919.95 + 500 = 1419.95 the sum of the sides, and 919.95 — 500 = 419.95 their difference; the three angles are 180° from which subtract angle A 36° 52′, and there will remain 143° 8′, divided by 2, gives 71° 34′ for half the angles at the base: then

As A C + B C, 1419.95	3.152273
is to A C — B C, 419.95	2.623198
so is the tang′ ½ (B — C), 71° 34′	10.477162
	13.100360
to the tangent of ½ (B — C) 41° 35′	9.948087

Then 71° 34′ + 41° 35′ = 113° 9′ = angle B
and 71° 34′ — 41° 35′ = 29° 59′ = angle C.

To find the side B C.

As the sine of C, 29° 59′	9.698751
is to the sine of A, 36° 52′	9.778119
so is A B. 500	2.698970
	12.477089
to B C, 600.26	2.778338

Case 4.—Given the three sides of a triangle, to find the angles.

From the angular point opposite the greater side, draw a perpendicular to that side, dividing it into two segments; then

As the base, or sum of the two segments of the base,
is to the sum of the other two sides,
so is the difference of the sides
to that of the segments of the base:
add half the sum of the segments of the base, and half their difference will give the greater segment: while the half sum subtracted from half the difference, will give the lesser segment.

Example.—In the triangle A B C, given the side A B, 562, A C 800, and B C 320; to find the angles.

Construction.—Draw the straight line A C = 800 equal parts from any scale; with a radius of 562 equal parts, and the centre A describe an arc at B, and with a radius of 320 and the centre C′ describe another arc, cutting the former at B; join A B and B C; then measure the angles by a protractor, or line of chords.

Now A B + B C =562 + 320 = 882 the sum of the sides, and A B — B C=562—320=242 their difference; then

As the base, or longest side, 800	2.903090
is to the sum, 882, of the sides	2.945469
so is the difference, 242, of the sides	2.383815
	5.329284
to A C—A D 266.81, the difference of the segments of the base	2.426194

then 133.405 is the half difference
and 400 is half the base;

therefore 533.405 is the greater segment of the base
and 266.595 is the lesser segment.

Then, to find the angle C B D.

As B C, 320	2.505150
is to C D, 266.6	2.425860
so is the sine of 90°, or radius	10000000
	12.425860
to the sine of C B D, 56° 25′	9.92′ 710

To find the angle A B D.

As A B, 562	2.749736
is to A D, 533.405	2.727057
so is the sine of 90°	10.000000
	12.727057
to the sine A B D, 71° 39′	9.977321
then adding C B D = 66° 25′	
gives the whole angle A B C = 128° 4′	
then 90 — 71° 39′ = 18° 21′ = angle A	
and 90 — 56° 25′ = 33° 35′ = angle C.	

From three parts of a triangle, including at least one side as a part given, the other three remaining parts have been found upon general principles; but when the triangle is right-angled, other solutions, more simple for general practice, may be given; these are founded upon the following proportions:

Let A B C be a right-angled triangle, right-angled at B; upon A B take any radius, A D; with A as a centre, and the radius A D, describe an arc, D G, cutting A C at G; draw D E and G F parallel to B C, cutting A C at E, and A B at F; then, by the definitions given, A C or A D is the radius, E D is the tangent, G F the sine, A F the cosine, and A E the secant of the arc C D. Now the sine, cosine, tangent, &c. of an arc, being the same as the sine, cosine, tangent, &c. of an angle drawn from the centre through the extremities of the arc, the following proportions result by similar triangles, A D E and A B C.

A D : D E : : A B : B C; that is, as a radius
is to the tangent of angle, A,
so is the base, A B,
to the perpendicular, B C.

By similar triangles, A F G and A B C,
A F : F G : : A B : B C; that is,
As the cosine of angle A,
is to the sine,
so is the base, A B,
to the perpendicular, B C.

So that having the angle, A, and the side, A B, given, the side B C may be found by either of these analogies; or, having the sides or legs A B and B C, angle A can easily be found.

By similar triangles, A E D and A C B,
A E : E D : : A C : C B; that is,
As the secant
is to the tangent
so is the hypothenuse, A C,
to the perpendicular, C B;
or, by similar triangles, A G F and A C B,
A G : G F : : A C : C B; that is,
As radius
is to the sine of angle, A,
so is the hypothenuse, A C,
to the perpendicular, C B.

So that having the angle, A, and the hypothenuse given, the perpendicular, B C, may be found; or, the angle, A, may be found from having the perpendicular and the hypothenuse given.

We shall now proceed to show the use of these analogies by examples.

In making any side radius, the other sides are sines, or tangents, of their opposite angles; when either of the legs, or sides, containing the right angle, is made radius, the other leg becomes a tangent of the opposite angle, and the hypothenuse the secant of that angle, and not of an opposite angle.

When the hypothenuse is made radius, the three sides are sines of their opposite angles; in this case the hypothenuse of the sine 90° is equal to the radius, and is therefore a constant quantity, its logarithm being 10.00000.

The radius, sine, tangent, or secant, being written upon any side, or supposed to be written, is called by the name of that side. Then,

As the name of any side
is to the name of any other side,
so is the former
to the latter side.
And the same analogy obtains on the contrary.

In analogies for finding the parts of a right-angled triangle, one of the terms, or names, may always be the radius, which will lessen the labour of the operation.

To exemplify what has been said:

If radius, or r, be written upon the leg A B, the other leg, B C, will be the tangent of angle A, and A C will be the secant of angle A. Therefore upon B C write t'A, which signifies the tangent of A, which will be the name of the side B C; also upon the hypothenuse A C, write sec' A, which signifies the secant of angle A, or name of the hypothenuse A C.

Again, when the leg B C is made radius, A B becomes the tangent of the opposite angle, C, and the hypothenuse the secant of angle C. Therefore, upon B C write r, and upon A B write t' C, and upon A C write sec' C; then *radius* is the name of the side B C, *tangent of* C is the name of the side A B, and *secant of* C is the name of the hypothenuse, or side, A C.

Lastly, when the hypothenuse A C is made radius, the legs A B and B C become the sines of their opposite angles; therefore, if r be written upon A C, write s' C, signifying *sine of angle* C, upon A B, and s' A, *signifying sine of angle* A, upon A B; then *radius* is the name of A C, *sine of* C the name of A B, and *sine of* A the name of B C.

It must be remembered, that whatever be the given parts, and whatever the parts required, any side of the right-angled triangle may be made radius, except when the two legs are given to find the acute angles, and this will furnish a method of proving the result. Therefore, if two of the sides be given, radius, being always constant, must always be one of the parts concerned; whence, if the two legs be given to find the angles, one of the legs must be made radius.

To find a Side.

As the term, or name on the given side
is to that on the required side,
so is the given side
to the side required.

And to find an Angle.

As the side made radius
is to the other given side,
so is radius
to the term or name upon that side.

Note.—From this property of a plane triangle, that the three angles are together equal to two right angles, or 180°, the following very useful corollaries arise.

Corollary 1.—When two angles of a triangle are given, the third is also said to be given; for it is the supplement of the other two, and may be found by subtracting their sum from 180°.

Corollary 2.—When one angle of a triangle is given, the sum of the other two may be found, by subtracting the given angle from two right angles, or 180°.

Corollary 3.—If one angle of a triangle be right, the other two are acute, and together make another right angle; and, if one of the acute angles be given, the other is also given, being the complement of the other given one, or what it wants of 90°.

PROBLEM I.—*Given the angles and hypothenuse of a right-angled plane triangle, to find the base and perpendicular.*

Example 1.—In the triangle A B C, right-angled at B, suppose the angle C, 55° 30′, and the hypothenuse, A C, 121 yards; required the sides A B and B C.

Geometrically.

Draw the indefinite line B C, and from the point C, with the chord of 60°, describe an arc, upon which lay off the quantity of the angle C, 55° 30′; then place the hypothenuse 121 equal parts from C to A, and from A let fall a perpendicular to B. Measure the sides A B and B C on the scale from which A C was taken.

By Calculation.

The hypothenuse A C being radius, then A B is the sine of the angle C, and B C the sine of angle A, or cosine of angle C. Hence,

To find A B.

As radius	10.000000
is to sine of C, 55° 30′	9.915994
so is A C, 121	2.082785
to A B, 99.719	1.998779

To find B C.

As radius	10.000000
is to cosine of C, 55° 30′	9.753128
so is A C, 121	2.082785
to B C, 68.535	1.835913

The base, B C, being radius, then A B is the tangent, and A C the secant of the angle C. Hence,

To find A B.

As secant of C, 55° 30′	10.246872
is to tangent of C, 55° 30′	10.162866
so is A C, 121	2.082785
to A B, 99.719	1.998779

To find B C.

As secant of C, 55° 30′	10.246872
is to radius	10.000000
so is A C, 121	2.082785
to B C, 68.535	1.835913

The perpendicular, A B, being radius, then B C becomes the tangent of the angle A, or the cotangent of the angle C; and A C becomes the secant of angle A, or cosecant of angle C. Hence,

To find A B.

As cosecant of C, 55° 30′	10.084006
is to radius	10.000000
so is A C, 121	2.082785
to A B, 99.719	1.998779

To find B C.

As cosecant of C, 55° 30′	10.084006
is to cotangent of C, 55° 30′	9.837154
so is A C, 121	2.082785
to B C, 68.535	1.835913

General Rule for Gunter's Scale.

Extend the compasses from the first term to the second; that extent will reach from the third to the fourth term; observing to take the line marked *Num.* for feet, yards, miles, &c., the line marked S. for sines of angles, and that marked T. for tangents. The radius is 90° of sines, and 45° of tangents.

Example 2.—In the triangle A B C, right-angled at B, let the hypothenuse, A C, be 1045 feet, and the angle, A, 35° 56′; what is the length of the base and perpendicular?

Example 3.—A ship, from latitude 20° 30′ north, sailed N.W. by N. 235 leagues; what is her departure from the meridian, what her difference of latitude, and what the latitude come to?

Example 4.—Suppose one end of a rope, 350½ fathoms long, fixed at the top of an eminence, and the other end brought down to the plane below, so that its direction make with the plane an angle of 50° 40′; required the perpendicular height of the eminence, and the space of the level covered by the rope.

PROBLEM II.—*Given the angles and one side, to find the hypothenuse and other side.*

Example 1.—In the right-angled triangle A B C, right-angled at B, let the angle at A be 35° 30′, and the side A B 294 feet; required the base, B C, and the hypothenuse, A C.

Geometrically.

Make A B = 294; at the point A make an angle of 35° 30′ from the line of chords; and from B raise the perpendicular B C. Measure B C and A C severally, by taking them in the compasses, and applying them to the scale from which A B was taken; then

By Calculation.

The hypothenuse, A C, being radius,

To find B C.

As cosine of A, 35° 30′	9.910686
is to sine of A, 35° 30′	9.763954
so is A B, 294	2.468347
to B C, 209.7	2.321615

To find A C.

As cosine of A, 35° 30′	9.910686
is to radius	10.000000
so is A B, 294	2.468347
to A C, 361.13	2.557661

The base being radius,

To find B C.

As cotangent of A, 35° 30′	10.146732
is to radius	10.000000
so is A B, 294	2.468347
to B C, 209.7	2.321615

To find A C.

As cotangent of A, 35° 30′	10.146732
is to cosecant of A, 35° 30′	10.236046
so is A B, 294	2,468347
to A C, 361.13	2.557661

The perpendicular, A B, being radius,

To find B C.

As radius	10.000000
is to tangent of A, 35° 30′	9.853268
so is A B, 294	2.468347
to B C, 209.7	2.321165

To find A C.

As radius	10.000000
is to secant of A, 35° 30′	10.089314
so is A B, 294	2.468347
to A C, 361.13	2.557661

Example 2.—In the triangle A B C, right-angled at B, suppose the base, B C, 374½ yards, and the angle, A, 52° 8′; required the other side, A B, and the hypothenuse, A C.

Example 3.—Suppose a ship sail S. W. by W. until she has made 409 miles of southing; required the distance sailed, and also how far she is west from the meridian of the place sailed from.

Example 4.—Observing the sun's altitude to be 30° 45′, and the shadow of a tree at the same time to fall 70 feet 3 inches distant from the tree, on the horizontal plane; what is the height of the tree, and what will be the length of a rope to reach from the extremity of the shadow to the top of the tree?

PROBLEM III.—*Given the hypothenuse and one side, to find the angles and the other side.*

Example 1.—In the right-angled triangle A B C, right-angled at B, let the hypothenuse, A C, be 350 feet, and the perpendicular, A B, 245 feet; required the angles, A and C, and the base, B C.

Geometrically.

Draw B C indefinitely toward C; at the point B make A B = 245, from a scale of equal parts, perpendicular to B C; and from the same scale take A C = 350; place one foot of the compasses in A, and the other, extending to the base, will cut it in C; then the angles are measured on the line of chords.

By Calculation.

The hypothenuse A C being radius,

To find angle C.

As A C, 350	2.544068
is to B A, 245	2.389166
so is radius	10.000000
to sine of C, 44° 25′ 37″	9.845098

To find B C.

As radius	10.000000
is to cosine of C, 44° 25′ 37″	9.853786
so is A C, 350	2.544068
to B C, 249.95	2.397854

The perpendicular, A B, being radius,

To find angle A.

As A B, 245	2.389166
is to A C, 350	2.544068
so is radius	10.000000
to secant of A, 45° 34′ 23″	10.154902

To find B C.

As radius	10.000000
is to tangent of A, 45° 34′ 23″	10.008688
so is A B, 245	2.389166
to B C, 249.95	2.397854

The base, B C, being radius,

To find itself.

As tangent of C, 44° 25′ 37″	9.991312
is to radius	10.000000
so is A B, 245	2.389166
to B C, 249.95	2.397854
As secant of C, 44° 25′ 37″	10.146214
is to radius	10.000000
so is A C, 350	2.544068
to B C, 249.95	2.397854

The side B C may also be found, independently of the angles, by means of the known property of a right-angled triangle; that the square of the hypothenuse is equal to the sum of the squares of the two sides.

For, since $AC^2 = AB^2 + BC^2$, it follows, that

$BC^2 = AC^2 - AB^2 = (AC + AB) \cdot (AC - AB)$;

and therefore $BC = \sqrt{(AC + AB) \cdot (AC - AB)}$

Or, Log. $BC = \frac{\text{Log. } (AC + AB) + \text{Log. } (AC - AB).}{2}$

From which B C is easily determined.

Example 2.—Suppose the hypothenuse of a right-angled triangle be 274.5 yards, and its base 196.25; what are the two acute angles?

Example 3.—Suppose a ship sailed between south and east 510 miles, and thereby made her difference of latitude, or southing, 315 miles; upon what course did she sail?

Example 4.—A ship sailed from latitude 49° 30′ north, between the south and west, 135 leagues, till, by a good observation, she is found in latitude 45° 15′; required the course on which she sailed.

PROBLEM IV.—*Given the base and perpendicular, to find the angles and hypothenuse.*

Example 1.—In the right-angled triangle A B C, right-angled at B, let the perpendicular, A B, be 650 feet, and the base, B C, 420 feet; required the acute-angles, A and C, and the hypothenuse, A C.

Geometrically.

Make B C = 420, taken from a scale of equal parts; from B raise the perpendicular A B = 650; from the same scale join A C to complete the triangle; then, with 60° taken from the line of chords, describe arches round the angles A and C; and their measures, applied to the same line of chords, will give the quantity of each angle.

By Calculation.

The base, B C, being radius,

To find angle C.

As B C, 420	2.623249
is to A B, 650	2.812913
so is radius	10.000000
to tangent of C, 57° 7′ 52″	10.189664

To find A C.

As radius	10.000000
is to secant of C, 57° 7′ 52″	10.265427
so is B C, 420	2.623249
to A C, 773.88	2.888676

The perpendicular A B being radius,

To find angle A.

As A B 650	2.812913
is to B C 420	2.623249
so is radius	10.000000
to tangent of A, 32° 52′ 8″	9.810336

To find A C.

As radius	10.000000
is to secant of A, 32° 52′ 8″	10.075763
so is A B, 650	2.822913
to A C, 773.88	2.888676

The hypothenuse, A C being radius,

To find itself.

As sine of C, 57° 7′ 52″	9.924237
is to radius	10.000000
so is A B, 650	2.812913
to A C, 773.88	2.888676

As sine of A, 32° 52′ 8″	9.734573
is to radius	10.000000
so is B C, 420	2.623249
to A C, 773.88	2.888676

The hypothenuse may also be found, independently of the angles, for $AC = \sqrt{AB^2 + BC^2}$; from which A C is easily determined.

Example 2.—In the rectilinear triangle A B C, rectangular at B, suppose the side A B 495.45 yards, and the side B C 560.5 yards; what are the acute angles, A and C?

Example 3.—Suppose three towns so situated, that A lies $35\frac{3}{4}$ miles south from B, and C lies $50\frac{1}{4}$ miles west from B; the bearing of A from C, and of C from A are required.

Example 4.—When the sun shines, if a steeple, 196 feet high, project a shadow 237 feet 9 inches, on the horizontal plane, what is the sun's altitude at that time?

With respect to taking angles by the theodolite, when we are not obliged to cross zero, subtract the less number of degrees from the greater, which will give the angle. But if we are under that necessity, subtract the greater number from 360 and add the less to the remainder for the angle.

Thus, suppose the index to stand at 145° in looking at one point or object, and at 253° in looking at another; or, suppose first at 253°, and then at 145°, then, in either case, 253° − 145° = 108° for the angle contained between the two objects.

Again: suppose the index stands at 254°, and we are obliged to cross zero in order to come to the other object, and then the index to stand at 15°; or suppose the index stands at 15° in looking at the first object, and at 254° in looking at the second, then, in either of these cases, 360°— 254° + 15° = 106° + 15° = 121°.

Figure 7.—*To find the height of an inaccessible object.*

Let C be the apex of a steeple, standing on the summit of a hill, and let A B be a straight line parallel to the horizon, so that the point C may be seen by a spectator from the points A and B, at a convenient distance from the eye above ground: let A B be 367 feet, the angle B A C = 44° 30′, and the angle C B D = 51° 20′; it is now required to find the height of the summit C, of the steeple above the horizon.

By subtracting 51° 20′ from 180°, a remainder of 128° 40′ is left for the angle A B C; and since the three angles of a plane triangle are equal to two right angles, the third angle A C B may be found by subtracting the sum of the two angles C A B and C B A from 180°, viz. 44° 30′ + 128° 40′ = 173° 10′ from 180°, which will leave a remainder of 6° 50′; so that in the right-angled triangle all the angles and one side are given, by which to find the side B C. Now, as the sides of a plane triangle are as the sines of the opposite angles,

	Thus,	or thus.
As sine of B C A 6° 50′....log. =	10·924520 ..	9·075480
is to sine of B A C, 44° 30′..log. =	9·845662 ..	9·845662
so is A B, 367 feet.....log. =	2·564666 ..	2·564666
to B C, which is 2,162 feet..log. =	3·334848 ..	12·410328
		9·075480
		3·334848

In the right-angled triangle A F C, right-angled at F, we have the hypothenuse, B C, and the acute angle, C B F: therefore, making the hypothenuse radius, the sides are as the sines of their opposite angles. Wherefore,

	Thus,	or thus.
As rad. sine of 90°.....log. =	10·..... =	10·000000
is to sine of 51° 20′.....log. =	9·892536 =	9·892536
so is 2,162 feet.....log. =	3·334848 =	3·334848
to C F, which is 1688 feet..log. =	3·227384 ..	13·227384
		10·000000
		3·227384

Figure 8.—*To find the distance between two inaccessible objects.*

Two inaccessible objects, D and C, are both visible from each of the two places A and B, whose distance is known, and each of which is visible from the other. Required the distance C D.

Observe the $< CAD = \alpha$, and $< DAB = \beta$ from A,
and $< DBC = \alpha$, and $< CBA = \beta$ from B.
Let $AB = a$,

Then, if we can find D A and A C, or D B and B C, the problem is reduced to this; find the third side when the other two sides and the angle included by them are given.

$$\text{Now, in } \Delta CBA, \frac{CA}{AB} = \frac{\sin. CBA}{\sin. ACB} = \frac{\sin. \beta}{\sin. ACB.}$$

$$\text{But } ACB = 180 - (ABC + CAB) = 180 - (\beta + \alpha + \beta)$$
$$\therefore \sin. ACB = \sin. (\alpha + \beta + \beta)$$
$$\therefore CA = \frac{a \sin. \beta}{\sin. (\alpha + \beta + \beta)}$$

$$\text{and in } \Delta DBA \frac{DA}{AB} = \frac{\sin. ABD}{\sin. ADB} = \frac{\sin. (\alpha + \beta)}{\sin. ADB}$$

$$ADB = 180 - (ABD + BAD) = 180 - (\alpha + \beta + \beta);$$
$$\therefore \sin. ADB = \sin. (\beta + \beta + \alpha);$$
$$\therefore AD = a \frac{\sin. (\alpha + \beta)}{\sin. (\beta + \beta + \alpha)}.$$

And thus knowing A C and A D, and $< CAD$, we may, by means of a subsidiary angle compute C D.

TRILATERAL, (from the Latin *tres*, three, and *latus*, a side,) a plane figure, or solid angle, having three sides.

TRIM, (from the Saxon *trimman*, to build,) in general, signifies to fit; as, *to trim up*, is to fit up.

TRIMMED: when a piece of work is fitted between two others previously executed, it is said to be *trimmed in* between them; thus, a partition wall is said to be trimmed-up between the floor and the ceiling; a post between two beams, a trimmer between joists, &c.

TRIMMED, is also applied to the putting of anything into shape, by cutting it away by degrees until it be of the proposed form.

TRIMMED-OUT, an expression applied to the trimmers of stairs, when brought forward to receive the rough strings.

TRIMMER, a small beam, into which the ends of several joists are framed. Beams of this kind are either stair-trimmers, hearth-trimmers, or tail-trimmers.

TRIMMING JOISTS, the two joists into which each end of the trimmer is framed. The distance of the trimming-joists, when employed in fire places, must be such as to take in not only the fire place, but the flues on each side of it. Trimming-joists ought to be stronger than the other joists, on account of the support they have to give.

TRINE DIMENSIONS, the dimensions of a solid, including length, breadth. and thickness; the same as *three-fold dimensions.*

TRIPARTITION, (from the Latin *tres*, three, and *pars*, a part,) the division of a number by three.

TRIPOD, or Tripos, (from *τρεῖς*, *three*, and *πυς*, *a foot*,) in antiquity, a three-legged seat from which the priests delivered their oracles.

TRIPTIC, or Triptych, a tablet in three divisions, of which the two outer fold over the centre one, by means of hinges, and form a cover to it. Triptics are employed to adorn the altars of churches over which they are placed; when open, they exhibit a painting, or representation, of some sacred subject.

TRISECTION, (from the Latin *tres*, three, and *seco*, to cut,) the division of anything into three equal parts; as the trisection of an angle, &c.

TROCHILUS, (from *τροχος*, *a wheel*,) an annular moulding, of which the section through the axis of the column is concave; more commonly denominated *scotia*. Its situation is generally between two tori. *See* Scotia, and Mouldings.

TROCHOID, (from *τροχος*, *a wheel*, and *ειδος*, *shape*,) a figure described by rolling a circle upon a straight line, with a pin or point in the circumference upon a fixed plane, in, or parallel to, the plane of the moving circle. *See* Cycloid.

TROPHY, (*τροπαῖον*, from *τροπη*, *to put an enemy to flight*,) in architecture, an ornament representing the trunk of a tree, charged around its circumference with military weapons, colours, and instruments of music.

TROUGH, (from the Saxon *troh*,) a vessel in the form of a rectangular prism, open on the top, having five sides enclosed for holding water.

Trough-Gutter, a gutter in the form of a trough, placed below the dripping eaves of a house, in order to convey the water from the roof to the vertical trunk, or pipe, by which it is discharged. They are only used in common buildings and out-houses. In buildings of the better class, the waterway is formed behind a blocking-course.

TROWEL. *See* Tools.

Trowel-point, a method of enrichment, applied to some mouldings of Norman and Byzantine character, such as to give them the appearance of having been indented with the point of a trowel.

TRUGG, a tray to carry mortar in.

TRUNCATED, (from the Latin *trunco*, to cut short,) signifies that quality of a solid by which the upper portion is cut off parallel to the base of the solid. Thus the frustum of a pyramid, cone, sphere, &c., is said to be truncated.

Truncated Cone, one which has the upper part cut off the frustum of a cone. *See* Cone.

Truncated Pyramid, one which has the upper part cut off; the frustum of a pyramid.

TRUNK, (from the French *trompe*, a long tube,) a vessel open at each end for the discharge of water, rain, &c.

Trunk, (from the Latin *truncus*, the body of a tree,) that part of a pilaster which is contained between the base and the capital.

TRUSS, (from the French *trousse*,) a frame of timbers so disposed, that if suspended at two given points, and charged with one or more weights in certain others, no timber would press transversely upon another, except by timbers exerting equal and opposite forces.

When one or more exterior timbers of a frame, suspended from two given points, are propped by the disposition of interior timbers at certain points in each of the exterior pieces, so as to resist the pressures of several weights, each acting upon one of the said points, without any tendency to bend or break any timber employed in the construction; the frame is called *a truss*, and each of the exterior timbers so propped in their length, are said to be *trussed*.

It is a principle in every such frame to have as few quadrangles as possible; all the interstices, or openings, should be triangles; and the intersections of the timbers should be as direct as possible, because oblique pressures exert prodigious strains, which require strong timbers of large scantlings to withstand them, and these would press upon the abutments so much as to make the truss sag by the compression of the intermediate joggles. Wherever two oblique thrusts press to the same point, no transverse timber should be interposed; for the shrinking of the transverse piece will also make the truss liable to sag. A truss of any extension may be made with a series of triangles composed of very short timbers; but then it will be necessary that every two adjoining triangles have the same common side, otherwise transverse strains will be produced. A truss may also be made of very short timbers, by making them balance each other by their position only.

Trusses are used for several purposes in building, as in partitions for supporting the floor above, to prevent it from communicating its pressure to the floor below, which may also be hung to the truss; particularly when there are neither bearing partition, nor trussed girders, which are shallow trusses, put between the ceiling and the floor, in order to stiffen the platform for walking upon. A roof of any considerable extent cannot be executed without one or more trusses; nor yet the centre of a bridge, or large vault.

Trusses employed in roofs and centerings, are placed from eight to ten feet distance in the clear, and in equidistant vertical planes. They may also be employed in the inclined sides of a roof, having their plane parallel to that of the covering, to counteract the pressure of the rafters downwards, and keep the lateral force thereby occasioned from acting upon the walls.

In all regular trusses, inclined timbers stand in pairs for mutual resistance, or counteraction. The names of the timbers which most frequently occur in trussed work are as follow: all inclined timbers are called *braces;* braces which either meet, or have ther direction to a point below their extremities, are called *struts;* hence every strut is a brace, but every brace is not a strut; those braces which form the exterior part of the truss, are called *principal rafters:* braces under the principal rafters, and parallel to them, are called *principal braces*, *discharging braces*, *auxiliary rafters*, or *cushion rafters*. Beams have various names, according as they have a higher or lower situation in the truss, or according as they perform the office of a tie or straining-piece; a beam acting as a tie, is therefore called a *tie-beam;* of which description it is always the lowest; a beam extending above the tie-beam, between a pair of principal rafters, is called a *collar-beam*, or simply a *collar*, or *straining-beam*, which name indicates its use; when a beam terminates the upper part of a truss, it is called *a camber-beam*, because it is made to slope in a small degree both ways from its middle towards each extreme on the upper edge; beams placed above the tie-beam, between a pair of posts, are called *straining-beams*. Posts when employed in trusses. stand always in pairs, except there be one in the middle: every such post is called by the general name of *truss-post:* when the head of a truss-post stands at the apex of a pair of principal rafters. it is called *the middle-post*, *crown-post*, or *king-post:* a pair of truss-posts, each of which is placed equidistant from the middle or ends of the truss, are called *side-posts:* when there is no crown-post in a truss, but one or more pairs of side-posts, the pair next the middle are called *queen-posts*. The annexed Plate shows the various parts of a truss in detail, together with various methods of connecting them together.

Figure 1.—No. 1. The top of the king-post, with part of the principals, and a strap connecting the three members.

No. 2. The method of joining the king-post with the tie-beam, and of screwing it up.

No. 3. The edge of the king-post, and a section of the tie-beam.

Figure 2.—Another method of joining the principals, king-post, and tie-beams.

No. 1. Parts of the principal rafters and king-post secured together by a branched strap.

No. 2. The method of strapping the king-post and tie-beam.

No. 3. Parts of the king-post and tie-beam, showing the method of wedging them.

Figure 3.—The method of forming a joggle, when the thick part at the bottom of the king-post is not sufficient for receiving the shoulder of the struts at right angles to their directions.

Figure 4.—A similar method, with a little variation.

Figure 5.—No. 1. Another method of joining the principals and king-posts by means of an iron dovetail, which is received into a mortise in the head of each principal.

No. 2. View from the top of the principals, showing the head of the wedge.

Figure 6.—Method of securing the tie-beam and principals when the king-post is made of an iron rod.

No. 1. The principals, with a part of the iron king-rod, and the hanging up of the tie-beam.

No. 2. The struts fixed to the iron king-rod, and the hanging up of the tie-beam.

Truss Partition, a partition with a truss consisting generally of a quadrangular frame, two braces, and two queen-posts, with a straining-piece between the queen-posts, opposite the top of the braces.

TRUSS POSTS. *See* Truss.

TRUSSED BEAM, TRUSSED GIRDERS, or GIRDING BEAMS. *See* Girders.

TRUSSED-RAFTER-ROOF, a roof which has no principal trusses, but which is composed entirely of trussed rafters. Such roofs are not uncommon in churches of the 12th or 13th centuries; they have a very pleasing perspective effect.

TRUSSELS, or TRESSELS, (from the French *tresteau*,) props for the support of anything, the under surface of which is horizontal; each trussel consists of three or four legs, attached to a horizontal part. When the trussels are high, the legs are sometimes braced. Trussels are much used in building for the support of scaffolding, and by carpenters and joiners for ripping and cross-cutting timber, and for many other purposes.

TRUSSING PIECES, those timbers in a roof that are in a state of compression.

TRY, (from the French *trier*, to bring to a test,) to plane a piece of stuff by the rule and square only.

TUBE, (from the Latin *tubus*, a pipe,) a substance perforated longitudinally, generally quite through.

TUBULAR BRIDGE. *See* Iron Bridge.

TUDOR ARCHITECTURE, considered in a general sense, is that style of architecture which prevailed during the Tudor dynasty. It is necessary, however, that the application of the term should be somewhat limited; for it cannot be expedient to adopt one title for so many and widely-different styles as those prevailing during that period; amongst which may be enumerated the late Perpendicular Gothic, the mixed or Elizabethan style, in which Italian details were introduced in buildings otherwise Gothic, and the Italian as practised by Inigo Jones and his cotemporaries.

As to the precise limitation of the term, there seems to be but little agreement amongst writers upon the subject; some applying it to buildings of the late Perpendicular style, in which ornamental details were profusely introduced, and which is, by other writers, designated as Florid Gothic. Under this signification, Ecclesiastical as well as Domestic and Civil structures are included; and of these, Henry VII.'s chapel, at Westminster, forms a characteristic example. The application of the term is strictly correct with respect to chronology, but is rather inconvenient as regards systematic arrangement, based upon peculiarities of style; and, besides this, there are so few important examples of this particular class, as scarcely to warrant the formation of a distinct style; they may be fairly considered as modifications of the Perpendicular.

Other writers would divide the style thus denominated into two divisions, Early and Late Tudor, the former term including the buildings just alluded to, and the latter being applied to those into which Italian details are introduced, and which are otherwise distinguished as Elizabethan. This plan we shall now adopt to a certain extent, excluding, however, the ecclesiastical buildings, which we include under the Perpendicular style, and conceding the term Tudor entirely to buildings of a domestic character. This arrangement, we must confess, is not without its objections; and we are inclined to think that the distinction between the first and second class of buildings is sufficiently great to entitle them to distinct designations, and, therefore, that the title of Elizabethan may be appropriately applied to the latter, to mark out a peculiar and separate style. We shall have before us, then, for consideration, the Early Tudor, and the Elizabethan or Late Tudor, styles.

The reign of Henry VII. introduced a new mode of living, and with it a new style of domestic architecture. With his marriage, the feuds between the houses of York and Lancaster came to an end, and a long season of internal peace seemed about to follow the troublous times of the preceding monarchs. Previous to this period, domestic architecture can scarcely be said to have had any existence; the mansions that had been erected were rather military than domestic, more like fortresses than dwellings. Now, however, with a prospect of peaceful times before them, men began to look for convenience rather than strength in their private mansions, and elegance began to be preferred to security. The halls of this and the following reign contained little of the fortified character of their predecessors beyond the battlements with which the walls were surmounted, and these, indeed, appear to have been preserved more for ornament than use: the thickness of the walls was reduced, the size of the windows enlarged, and the other arrangements influenced by the requirements for comfort and convenience rather than of security.

We know little of Henry VII.'s buildings of this class; of the palace erected by him at Shene or Richmond, not a vestige now remains, but some particulars concerning it are given in the Survey of 1649, when it was offered for sale by the Commissioners of Parliament. It abounded with bay windows of capricious design, with rectangular and semi-circular projections: and was adorned with many octagonal towers, surmounted with bulbous cupolas of the same plan, having their angles enriched with crockets.

Henry VIII. was not only a great builder himself, but encouraged his nobles to follow his example; so that there was no lack of examples in his reign. Henry, himself, is said to have built or repaired the following mansions:—

Beaulieu, or Newhall, Essex.

Hemsdon, Herts, originally built by Sir John Oldhall, temp. Edward IV.

Ampthill, Bedfordshire.
Nonsuch, Surrey.
York Place, Whitehall, Westminster.
Bridewell and Blackfriars, London, for the reception of the emperor Charles V.
St. James's, Westminster.
Kimbolton, Huntingdonshire, the jointure of the divorced Queen Catherine of Arragon.
Sheriff Hutton, Yorkshire, given for the residence of Henry, Duke of Richmond, the king's natural son.
King's Langley, Herts.

When the monarch set himself so vigorously to work in building and repairing, it is no matter of surprise to see his courtiers following in the same steps; and, accordingly, we find that many and sumptuous were the mansions erected by them. Foremost in such works stands Wolsey, amongst whose principal buildings may be enumerated Hampton Court Palace; York House, afterwards Whitehall; his episcopal residence at Esher, Surrey; the college of Christchurch, Oxford, and another at Ipswich. Edward Stafford, Duke of Buckingham, erected a magnificent palace at Thornbury, Gloucestershire; Charles Brandon, Duke of Suffolk, one at Grimsthorpe, Lincolnshire; the Duke of Norfolk, and his son, the Earl of Surrey, those of Kenninghall, Norfolk, and Mount Surrey, near Norwich. Amongst others may be mentioned Haddon Hall, Derbyshire; Coudray, Sussex, destroyed by fire in 1793; Hever Castle, Kent; Gosfield Hall, Essex, perfect; Hengreave Hall, Suffolk, perfect; Layer Marney, Essex, now in ruins; Raglan Castle, Monmouthshire, in ruins; Hunsdon House, Herts, rebuilt; South Wingfield, Derbyshire, dilapidated; Hill Hall, Essex; Wolterton, East Barsham, Norfolk, in ruins.

The plan of the larger mansions of this period was quadrangular, comprising an inner and base court, between which stood the gate-house. On the side of the inner court, facing the entrance, the principal apartments were placed, amongst which may be enumerated the hall, the chapel, the great chamber and dining-room, and were connected with a gallery for amusements running the whole length of another of the sides of the quadrangle. Several examples of this description are to be found, of which Hannaker House, near Midhurst, Sussex, will give us a good idea; this mansion was built round a court, with the entrance under an embattled gate-house, flanked by small octagonal towers on the south; a square tower stood at the south-east angle; the chapel and other apartments on the east, and the hall and principal rooms on the north. In mansions of less pretensions, the gate-house stood in advance of the building, connected with it only by mantle walls, as at East Barsham, Norfolk.

The materials of which such buildings were constructed were either brick or stone, and sometimes both combined, the main building being of brick and the dressings of free-stone; this practice was very common. Bricks of two colours, usually black and red, and sometimes highly glazed, were employed to variegate the surface, the darker-coloured bricks being disposed in the form of lozenges and other figures; and in some instances the brick-work was rendered in ornamental plaster, as at Nonsuch. Moulded brick-work and terra-cotta were also employed for decorative purposes; medaillions, or busts of terra-cotta were frequently inserted in small circular and other-shaped cavities in the walls, and heraldic devices, cognizances, &c. were dispersed in various parts of the building.

The details and style of ornament adopted in those houses are, for the most part, the same as those to be found in ecclesiastical buildings of the same period, the principal difference consisting in the different composition and arrangement of the various parts. Amongst the more striking peculiarities may be reckoned the gate-houses, the numerous turrets and chimneys, the beautiful bay and oriel windows, the roof, ceilings, and panelled wainscot round the internal walls.

The gate-houses were very prominent features in these buildings, of lofty elevation, containing several apartments; they seem to have received a great deal of attention as to design, &c., and were more beautifully ornamented than almost any other part of the building. They were mostly placed in the centre of one of the sides of the court, and were usually embattled, and flanked by more lofty turrets at the angles. Stair-case turrets, rising above the general elevation, served to relieve the general outline, and of these there were frequently several in the angles and other parts of the court as occasion demanded; the gables, also, were often flanked with turrets. Grouping well with these turrets, the heavy masses of chimneys stood out in bold relief, and gave great character to the elevation. Previous to this date, chimneys had been rarely used, and, when employed, had been made of secondary importance in the general design; but now they not only began to be extensively used, but formed very prominent objects in the elevation; and received, probably, as much attention in the design as any other part of the edifice. They were of lofty proportions, circular or octagonal in plan, and usually clustered together in groups of two, four, or more. The shafts were ornamented with various devices, as roses, fleur-de-lis, &c., moulded on the surface; at other times they were carved with spiral flutings, and ornamented in an infinite variety of ways; the tops, or caps, as they may be called, were richly moulded, and, indeed, the inventive powers seem to have been exhausted in the multitude of designs for the enrichment of this member of the edifice. The projecting windows form a very characteristic feature of the style: they are of two kinds, those which rise immediately from the level of the ground being termed *bays;* and those which project out in the upper part of the building, being corbelled out so as to overhang that below, are termed *oriels.* Both kinds of windows are erected on plans of various figures, but more especially upon those of a rectangular, semi-octagonal, or semi-circular plan. Sometimes they are restricted to a single floor, while at others they are carried up through several. The bay-window is very common in large halls, where it is found at the upper end forming a recess at the side of the dais; sometimes we find a bay on either side of the dais; such windows were usually loftier than the others, being carried from about three feet from the ground to the ceiling. Oriel windows are principally confined to the buildings of Henry VII.'s and the early part of Henry VIII.'s reign, but bays were common in the reign of Elizabeth.

Many of the great halls of this period had open timber-roofs, of bold construction and beautiful design: they are mostly what are termed hammer-beam roofs. *See* ROOF. The most remarkable are those erected by Cardinal Wolsey, at Hampton Court Palace, and at Christ Church Oxford, both of which are 40 feet in width: many others are to be seen in the halls of colleges at Oxford and Cambridge, and in the inns of court in London. The ceilings were usually of timber, divided into compartments by the main timbers of the floor above, and sometimes into smaller compartments by the joists, the timbers being either moulded or chamfered on the edge. Sometimes the flooring-timbers are concealed by panels with ribs of oak, which divide the surface into compartments of various forms, the ground between the ribs being either of wood or plaster. At the intersections of the ribs, bosses of foliage and devices in wood or plaster were frequently introduced.

The walls of the principal chambers were often lined with carved wainscoting in panels, which were small, and mostly of what is termed the linen pattern; sometimes they were enriched with carved work in the shape of ciphers, cognizances, chimeras, mottoes, &c.

The windows of this style are usually square-headed, divided into lights by mullions and transoms, the latter being frequently enriched with a series of small battlements on the top, and the lights arched and cusped.

The following examples will serve to afford some idea of the general character of the buildings of this period :—

Hampton Court Palace, commenced in 1514, was erected by Cardinal Wolsey; it is a very magnificent building, comprising no less than five courts. In the centre of the entrance-front is a square tower, flanked by an octagonal turret at each angle, which rises above the general elevation of the tower; in the lower story is the grand gateway, with obtuse-pointed or Tudor arch, over which in front and rear is a rich oriel window. The walls are crowned by battlements of open work, and each turret is terminated by an octagonal roof, the contour being a curve of contrary flexure.

On the right and left of the tower the buildings are partly modernized, but at each extremity is one of the old gables, the raking cornices of which are ornamented with figures of griffins. From these extremities wings project towards the front at right angles to the body of the building. The first quadrangle, which is entered by the above gateway, consists of the dwelling-house, the walls of which are crowned with embattled parapets; the windows are square-headed, and the doors covered by plain arches. In the centre of the side of this quadrangle, which is opposite to the grand entrance, is another tower similar to, but smaller than the first, and flanked by rectangular battlemented turrets; through this tower is an arched passage leading into the second quadrangle, and over it an oriel window.

The second quadrangle is smaller than the first, the left side being occupied by the grand hall, which is covered by a lofty roof; the walls are strengthened by buttresses, and the windows, which are pointed, are divided by mullions carried perpendicularly to the head. The right-hand side of the court is occupied by a colonnade designed by Sir Christopher Wren. In the third side is a tower in a line with the two previously mentioned, containing a passage leading to the third quadrangle, the ceiling of which is enriched with delicate fan-tracery. The third quadrangle is surrounded by an arcade supporting the fronts of the buildings; the walls of which are of red and dark brick set in diamond patterns, and are crowned with plain and perforated battlements. This court was modernized in the reign of William III. The windows of the ancient building are distributed without respect to symmetry; the frames are rectangular, and in general of greater width than height; they are divided vertically by one or more mullions, and some by transoms running across at about mid-height; the lights are obtusely arched at the head.

The timber-roof of the hall is of very good construction, and of beautiful design. Each frame is formed by two inclined principals, separated by a straining-piece at top, and tied together at about mid-height by a collar-beam; a hammer-beam at the bottom of each principal projects for about a quarter the entire width of the hall, and is supported at the extremity by a curved brace resting on a wall-post, which again is supported on a corbel at some distance below the top of the wall. The extremity of the hammer-beam carries a pendant, and above it springs a curved rib which meets one from the opposite side of the roof, immediately under the centre of the collar-beam, and thus forms an obtuse-pointed arch. The contour of the roof, as seen from below, will therefore present the appearance of a trefoil; it is enriched with pierced panelling, and other carved work.

Thornbury Castle, Gloucestershire, was commenced about 1511; the parts at present existing, having been built in the reign of Henry VIII., by Edward Stafford, Duke of Buckingham, who was engaged on it for ten years, but was not suffered to live to complete it. "The towers at the entrance to the inner court are bold in design; the projecting machicolations, still preserved, are very good examples. The bay-windows of the great hall are beautifully composed; the plans of the upper and lower parts vary, the one being a combination of five semi-circles of four lights in each, whilst the latter is angular, and more solid in construction."

The great oriel window is very beautiful, as are also the enriched chimney-shafts, fire-places, &c., illustrations of which will be found in *Pugin's Examples*.

The following description of a mansion of this period, at Midhurst, in Sussex, is given by Warton :—"We enter a spacious and lofty quadrangle of stone, through a lofty Gothic tower with four angular turrets. The roof of the gateway is a fine piece of old fret-work. There is a venerable old hall, with a noble oak-raftered roof, and a large high range of Gothic windows. Opposite the screen is the arched portal of the buttery. Adjoining the hall is a dining-room, the walls painted all over (as was anciently the mode soon after the beginning of the reign of Edward VI.,) chiefly with histories (out of perspective) of Henry VIII.; the roof is in flat compartments. A gallery with window-recesses, or oriels, occupies one side of the quadrangular court. A gallery on the opposite, of equal dimensions, has given way to modern convenience, and is converted into bed-chambers. In the centre of the court is a magnificent old fountain, with much imagery in brass, and a variety of devices for shooting water. On the top of the hall is the original louvre or lantern, adorned with a profusion of vanes. The chapel, running at right angles with the hall, terminates in the garden with three large Gothic windows."

Hengrave Hall, Suffolk, was built, as we learn from an inscription on the outside of the curious oriel window, in 1538. It consists of an open court surrounded on three sides by a gallery, communicating with all the apartments, and lighted by windows looking into the court: on the other side is the hall, (34 feet by 25,) which is lighted by a bay and two other windows, also looking into the court. The principal part presents a very picturesque appearance, measuring about 160 feet in length. The building is of brick and stone, and the gateway, which is in good preservation, is of peculiar design.

The manor-house at East Barsham, Norfolk, is composed almost entirely of bricks: it was commenced in the reign of Henry VII., and finished in that of his successor. The following description is given by Mr. Bury :—"The walls of the principal front are nearly on one plane, being broken only by the porch in the centre; and octagonal turrets of different sizes are so disposed as to give a variety of outline to the combination. The hall is to the left of the porch by which it is entered; the great parlour and principal apartments are beyond, or at the back of it. The windows are large, and must have given the rooms a cheerful appearance. The building consists of only two stories, except in one part, where another is added as a tower. The upper string-courses are bold in moulding, and rich in cast ornaments and panels; these are surmounted by moulded battlements with beautiful traceried panels. The stack of ten chimneys at the

west end of the hall, and the turret-terminations, are fine in design and execution. "The building, which measures 140 by 58 feet, has a gate-house tower, about 40 feet in front of the porch (a paved court intervening;) on this, if possible, a still greater degree of moulding and enrichment has been bestowed; comprising figures, armorial bearings, battlements, and panelling, which are all executed in brick in a surprising manner."

Elizabethan, or Late Tudor.—During the whole of the above period, the influence of Gothic art had been disappearing throughout the continent. As early as the middle of the fifteenth century, Brunelleschi had introduced that partial revival of the classical styles which has been denominated Italian, from the name of the country where it first made its appearance, and where it afterwards chiefly flourished. This revival had been practised throughout the continent, ere it reached this country, where the Gothic maintained its position for a very long time, and even after the introduction of the Italian, gave place but slowly, and not without a severe and lengthened struggle. Our constant intercourse with the continent during the reign of Henry VIII., must have had considerable influence on the arts in this country, the effects of which are evident in the later buildings of this reign; in the hall of Hampton Court Palace are introduced details of Italian design, and in many other buildings of the same or later date. The next reign brings us a step further in this direction. John of Padua, an Italian architect, was introduced into England under the patronage of the protector Somerset; and from his designs were erected the mansions of Sion House, and Longleat, Wilts. In the reign of Elizabeth, however, the Italian style of art began to make more rapid strides, and assume a position of equality with the Gothic. Early in her reign, the treatises of Lomazzo and Philibert de Lorme were translated into English, and a work upon architecture was published by John Shute, an artist and architect who had been sent out to Italy by Dudley, Duke of Northumberland. From this and other circumstances, it is not difficult to account for the change which came over architecture during this period. This change, however, was rather in matters of detail than in general construction, although a considerable improvement would seem to have been made in the internal arrangement of houses, which were altogether more commodious. Up to this time, the mansions of the nobility were usually only one story in height, and in plan greatly deficient in the requirements incidental to the improved social condition of the country; but now we have lofty buildings, and considerable skill exhibited in the disposition of the apartments; indeed, we have ample evidence that no building was now undertaken, without the previous arrangement of a well-considered plan.

The plans of buildings of this reign were of varied character, sometimes quadrangular, having three sides surrounded with buildings, with the portico in the centre, the quadrangles being usually surrounded with an open arcade or corridor. This, however, was but one plan out of many others, some of which were exceedingly curious; for instance:—Longford Castle, Wiltshire, was in plan similar to the ecclesiastical device on which the doctrine of the Trinity was illustrated; it was a triangular court surrounded with buildings, having a circular tower of the same height as the other parts of the building, at each angle, from each of which in the interior was carried a row of buildings meeting in the centre.

A mansion, designed by John Thorpe, the architect, for his own use, was elevated on a plan which represented his own initials in monogram; and that this was designedly so arranged, we learn from the epigraph appended to his design, which is as follows:

> "Thes 2 Letters I and T
> "Joyned together as you see
> "Is meant for a dwelling-house for mee" "John Thorpe."

The principal deviations in matters of construction from the buildings of the preceding era, consist in the multiplication of bay-windows; the addition of large projecting porticoes richly ornamented; the importance given to the halls and staircases, which became very spacious and magnificent, often occupying a large proportion of the mansion; the increased length and spaciousness of the galleries, which frequently exceeded 100 feet in length; the increase of lighting area, the windows being greatly enlarged in size, having sometimes three or four tiers of openings; the magnificence of the fire-places, which frequently reached to the ceiling, and were enriched with carving and sculpture, in the shape of heraldic devices, &c.; the beautiful and richly-moulded plaster ceilings, with deep cornices, also of plaster: the walls were either panelled or whited, and ornamented with labels containing poetry, maxims, &c. Another peculiarity is observed in the large and imposing flights of steps, and in the noble terraces in front of the mansions: these were raised one above the other, approached from one to the other by broad flights of steps, and defended on the edge with richly-perforated parapets or balconies.

The general characteristic of the style is manifested in the admixture of Italian details with Gothic features and designs. Quasi-classic columns and pilasters are frequently introduced, but they are often ill-proportioned and very inaccurately and rudely profiled; they are frequently banded at intervals in their height with circular or square blocks, which when square, are mostly ornamented with diamond or jewel-shaped projections, a species of ornament which is of frequent general application: at other times the shafts were decorated with grotesque ornaments of various kinds, flutings, &c. Arcades, with circular arches, are also common, the space from pier to pier being often of an extravagant width, their height sometimes running up into the entablature, which member, again, is rarely or never found continuous or unbroken, and it is frequently frittered away with scroll and other ornaments. The bay-windows, parapets, and gables are usually terminated by perforated crestings of scroll or geometrical pattern; this perforated work and scroll ornament in general, as also the lozenge and other ornaments, standing in relief upon the surface to be enriched, are very profusely employed, and may be considered decidedly characteristic of the style. The shell-roofed niche and caryatid columns are also frequent. The plaster ceilings were usually of very elaborate design, and very richly moulded; they form a very praiseworthy feature in buildings of this date. Heraldic devices and grotesques were not unfrequently employed in general ornamentation.

It would be superfluous to enter into a more detailed description, for the style altogether is so abnormal and intricate, that a full description would necessitate illustrations of almost every example. Very contrary opinions have been held respecting the merit of this style; for our own part, while we must condemn it as being unscientific in construction, and impure, if not barbarous, in taste, at the same time we are inclined to allow it a great deal of credit for its picturesque appearance. It certainly will not stand the test of severe criticism.

Amongst the more noted architects of this time we may mention the following:—Robert Adams, Surveyor of Works to Elizabeth; John Shute, author of a book upon architecture;

Bernard Adams; Lawrence Bradshaw; and John Thorpe, who has left us a book of his designs, which are very numerous: he was engaged upon a great many works, of which the principal are—Holland House, Middlesex; Longford Castle, Wilts; Wollaton Hall, Notts; and Audley End, Essex. Gerard Christmas was engaged upon Northumberland House, as was also Moses Glover and Bernard Jansen; of whom the second was further employed in the completion of Sion House, and the latter in the erection of Audley Inn. Robert and Huntingdon Smithson, father and son, were engaged upon Wollaton House, Notts, and Bolsover, Derbyshire. Thomas Holte was architect of the Public Schools, and of the quadrangles of Newton and Wadham Colleges, Oxford.

Several mansions of this style were erected or completed during the reign of James I., and even the early works of Inigo Jones were in this style, as, for instance, the quadrangle of St. John's College, Oxford. The pure Italian, however, was rapidly gaining the ascendancy, and was destined to be permanently introduced by this same man in the early part of the 17th century.

The following is a list of some of the principal mansions belonging to this period of architecture. As a description, apart from illustrations, would be of little use, we beg to refer the reader to a beautifully-illustrated work upon the subject by Mr. Nash, entitled 'Mansions of England in the Olden Time.'

Name.	Date.	County.	Present State.
Basinghouse	1560	Hants.	In ruins.
Gorhambury	1565	Herts.	Do.
Knowle	1570	Kent	Perfect.
Penshurst	„	Kent	Do.
Kenilworth	1575	Warwick	In ruins.
Hunsdon	„	Warwick	Rebuilt.
Burleigh	1577	Lincoln	Perfect.
Longleat	1579	Wilts.	Do.
Westwood	1590	Worcester	Do.
Hardwick Hall	1597	Derby	In ruins.
Holland House	1607	Middlesex	Perfect.
Bramshill	„	Hants.	Do.
Castle Ashby	„	Northampton	Do.
Summer Hill	„	Kent	Do.
Charlton	„	Wilts.	Restored.
Hatfield	1611	Herts.	Perfect.
Longford Castle	1612	Wilts.	Do.
Temple Newsham	„	Yorkshire	Do.
Charlton	„	Kent.	Do.
Bolsover	1613	Derby	Dilapidated.
Audley Inn	1616	Essex	Perfect.
Wollaton	„	Notts.	Do.

There is one class of houses which reached its zenith during the reign of Elizabeth, and which deserve some mention in this place: we allude to the half-timbered houses. They were composed of timber frame-work, and present the appearance of brick-nogging, the spaces within the frame being plastered: the timbers are arranged sometimes vertically, with horizontal beams at intervals, and this arrangement has a very pleasing appearance; at other times the secondary timbers were ranged diagonally, or disposed so as to form geometrical figures, such as squares, triangles, diamonds, &c., and, not unfrequently, curved timbers were introduced. Such houses are peculiar in having the upper stories of larger dimensions and projecting over the lower ones, and are remarkable for their barge-boards overhanging the gables. These are frequently of very beautiful design, and delicately carved; they have a singularly pleasing appearance. Wooden corbels, in the shape of grotesque figures, are also common. The plaster-work was frequently ornamented with devices of various kinds, either in relief or recession.

The counties of Cheshire and Shropshire were peculiarly noted for country mansions of this class; and many examples are to be found in the towns of Chester, Shrewsbury, Leicester, Warwick, and Ipswich. They invariably present a very picturesque appearance. The following is a list of some of the principal examples; and, for further information respecting them, we refer the reader to a work upon the subject by Mr. Habershon:—

The Oaks, West Bromwich:	... date ...	Henry VIII.
Elmley Lodge, near Droitwich	„	Charles I.
Old House, Market Place, Preston	„	Do.
Bramall Hall, near Stockport	„	Elizabeth.
Hop-pole Inn, Bromsgrove.		
Pitchford Hall, near Shrewsbury.		
Salwarp Court, near Droitwich.		
Samlesbury Hall, near Blackburn	„	Edward VI.
Hall-i'-the-wood, near Bolton	„	Charles I.
Ince Hall, near Wigan.		
Park Hall, near Oswestry.		
Moreton Hall, near Congleton.		
Mere Hall, near Droitwich.		

For further particulars on the subject of this article, *see* House.

TUDOR FLOWER, a flat flower or leaf of a diamond shape, placed upright on its stalk, much used in the crestings of Perpendicular work.

TUFA, a calcareous earth, composed of broken and concreted shells, or the deposit from water impregnated with lime.

TUMBLING-IN, or Trimming-in: when a piece of timber is to be fitted between two others, given in position, the fitting is called *tumbling-in;* a trimmer may be tumbled-in between two joists, and the purlins of a roof between two of the rafters, when they are not bridged over them.

TUN OF TIMBER, about 40 solid feet.

TUNNEL, a subterranean passage.

TURNING PIECE, a board with a circular edge, for turning a thin brick arch upon, as the breast of a chimney.

TURRET, a small tower; frequently found attached to a larger one at its angles, or at the angles of buildings; they are sometimes built out to contain stairs.

TUSCAN ORDER, an ordinance with a column and entablature the same as the Roman Doric, divested of its triglyphs, mutules, and guttæ, the members of the entablature being continued throughout the whole length, without interruption.

It has been customary to consider this method as a separate order; but there would seem to be little reason for so doing; for indeed it is little more than a variation of the Roman Doric, which, divested of its enrichments, is to all intents and purposes Tuscan.

We find no remains of a complete Tuscan order amongst the relics of antiquity; the present delineations of the order being determined by the interpretations which different architects have put upon the passage in Vitruvius, in which it is described. As this description is somewhat obscure, it is not unnatural that we should find that different conclusions have been arrived at upon the subject: thus we have different designs by Palladio, Vignola, and Scamozzi. Although we have no remains of a perfect order, we have examples of Tuscan columns, amongst the more noted of which stands the Trajan column at Rome. Vitruvius does not speak of this as a distinct order, although he alludes to the construction of Tuscan temples. He makes the column six diameters in height, with a diminution of one quarter of a

diameter; the base and capital each one module in height. He decides no height for the architrave or cornice, omits the frieze, but places mutules over the architrave, which are to project one-fourth of the total height of the column, including base and capital. He does not provide a pedestal.

Palladio makes the total height of the order nine diameters and three-quarters, of which he gives six to the column; the height of base and capital each measuring half a diameter; he provides no pedestal, but places the base on a plinth whose height is equal to one diameter.

Serlio makes the height of the architrave half a diameter, and gives an equal height to the frieze and cornice. His pedestal consists of a plinth and base, a die and cymatium, the whole being a third of the height of the column.

Scamozzi assigns as the height of the entablature one-fourth of the total height of the column, less half a diameter; and makes his pedestal of the same height. He also places a sort of triglyph in the frieze.

Plate 1.—The entablature, capital, and base of the Tuscan order finished.

Plate 2.—Outline, with the measures of the various members.

TUSK, (from the Saxon *tysos*, a fang,) a bevel shoulder made above a tenon, and let into a girder to strengthen the tenon.

TYMPAN, (from *τυμπανον*, *a timbrel*,) the hollow recessed part of a pediment, being either a plane triangle, or filled with ornaments of sculpture raised from the plane of the triangle.

Though the pediments of the ancient Greeks were very low, they were long enough to admit of the most beautiful sculpture; as that of the Temple of Minerva at Athens, now deposited in the British Museum.

Tympan also signifies the die of a pedestal, or the panel of a door.

TYPE, the canopy over a pulpit.

U.

URB URN

UMBER, a fossil brown substance, used by painters, which grinds freely, and bears a good body. When burnt, it furnishes the most natural imitation of gold: with a mixture of white, it resembles the colour of new open wainscot. It dries quickly, with a considerable gloss. It has its name from the ancient province of Umbria in Italy, whence it was originally obtained; but is also found in Germany, Spain, Egypt, Cyprus, and other parts of the Turkish dominions, from which last what is brought into England mostly comes. Dr. Hill and Mr. De Costa consider it as an earth of the ochre kind, which might be found in considerable quantities in England and Ireland, if properly looked after; several large masses of it having been thrown up in digging on the Mendip hills, Somersetshire, as well as in the county of Wexford, Ireland. It is also met with occasionally in the veins of lead-ore in Derbyshire and Flintshire.

UNDECAGON, (Greek *ενδεκα*, *eleven*, and *γωνια*, *an angle*,) a figure of eleven sides.

UNDERCROFT, a crypt, or subterranean apartment.

UNDER-PINNING, the act of bringing a wall up to the ground-sill, or sometimes that part of the wall itself. The temporary support of a wall whose foundations are defective, or the formation of new foundations.

UNGULA, of a cylinder, or cone, a part of the solid comprehended by part of the curved surface, the segment of a circle, which is part of the base, and another plane.

UNIVERSITY, (from the Latin *unus*, one, and *verto versus*, to turn,) a collection of colleges for teaching the various branches of knowledge. In an architectural point of view, the term is applicable to the houses, or edifices, in which the classes are held.

UPHERS, fir poles, from 4 to 7 inches in diameter, and from 20 to 40 feet in length; they are frequently hewn on the sides, so as not to reduce the wane entirely. They are of great use in scaffolding and ladders; and are also employed in slight roofs, where they are slit.

UPRIGHT, the elevation of a building. The term is rarely used, *elevation* being more commonly employed.

URBIN, or URBINO, a name frequently given to that most sublime and excellent painter, Raphael Sanzio, from the place of his birth. He was the son of an indifferent painter, named Sanzio, and was born on Good Friday, 1482. He was employed by the popes Julian II. and Leo X., who loaded him with wealth and honours; and the cardinal De St. Bibiana held him in such high estimation that he offered him his niece in marriage: but he declined this honour, from an expectation he entertained, founded upon the promise of Leo X., of being made a cardinal himself. His pictures are to be found principally in Italy and Paris. That of the *Transfiguration*, preserved at Rome, in the church of St. Peter Monterio, is reckoned his master-piece. His person was handsome, and his manners were polite, affable, and modest, though he lived in the utmost splendour. He was not only the best painter in the world, but perhaps the best architect too; on which account he was employed by Leo X. in building St. Peter's church at Rome. This engagement prevented his acceptance of an invitation into France from Francis I., for whom he had painted a *St. Michael and the Holy Family*, and had been remunerated by that monarch with sums so far beyond his expectation, that he resolved to show his gratitude by a performance, in which he even surpassed himself: this was the *Transfiguration* above alluded to intended as a present to Francis; but he died before the picture was quite finished, and it was detained at Rome. His death happened on his birth-day, 1520, when he had completed his 38th year; the consequence of his passion for the fair sex, and the injudicious treatment of his physicians. His celebrated *Cartoons*, for which Louis XV. offered a hundred thousand pounds, were purchased by Rubens for Charles I. and brought to England, and have successively graced the palaces of Hampton Court, Buckingham House, and Windsor Castle. A considerable jealousy existed between this artist and Michael Angelo, which sometimes manifested itself in a manner not very creditable to either. Raphael frequently exercised himself in sculpture, and excelled as much in it as in painting and architecture. A *Jonas*, of the size of life, which is deemed his *chef-d'œuvre* in this line, is shown in the chapel of Madonna del Popolo, at Rome, the cupola of which he also painted.

Urbin is also a name sometimes given to Bramante, from his having been born in the province of Urbino. *See* Bramante.

URN, (from the Latin *urna*,) a vase of a circular form, used as a terminating ornament upon an acroter, or the like. Urns were not much employed in the celebrated edifices of antiquity.

V.

VAGINA, (Latin,) the lower part of a Terminus, resembling a sheath, in which the lower part of the statue is inserted.

VALLEY, (from the Latin, *vallis*, a hollow,) the internal angle of two inclined sides of a roof.

Valley-Board, a board fixed upon a valley-rafter for the leaden gutter to lie upon.

Valley-Rafter, the rafter under the valley, or that which supports the valley.

It is evident, that since the internal angle is above the roof, the external angle is under it; and, in hip-rafters, that since the external angle is outward, the internal angle is inward; therefore, the hipped angles will be stronger than the valleys, and consequently require timbers of less scantling to support them. This circumstance should be attended to in the description or particulars of a building, as the judgment of the architect will be shown in such discriminations.

Valley-Rafters, in old books, are called *sleepers;* but in this sense the term is antiquated. *See* Sleepers.

Valley-Pieces, the same as Valley-Rafters. The term is used in some parts of the country, particularly in Devonshire.

VALLUM, a rampart or raised wall or mound erected for the purpose of defence.

VALVED, anything that opens upon hinges.

VANE, a plate of metal turning on a vertical spindle, and fixed on the summit of a tower, spire, or other elevated building, to show the direction of the wind. The custom of placing vanes on church-steeples is very ancient; and as they were commonly made to represent the figure of a cock, they have been thence termed *weather-cocks*. In late Gothic buildings, they frequently present the appearance of little flags, perforated with heraldic devices, &c.

VANISHING LINE, in perspective, the intersection of the parallel of any original plane with the picture.

Vanishing Point, that point to which all parallel lines in the same plane tend in the representation.

VARIATION OF CURVATURE, the change made on a curve, so as to make it quicker or flatter in every succeeding part; as the curvature of the quarter of an ellipsis terminated by the two axes is continually quicker from the extremity of the greater axis to that of the lesser.

VARIETY, (from the Latin, *vario*, to change,) the agreeable disposition of the parts of an edifice.

VARNISH, a preparation used to preserve and put a glossy surface upon painted articles. It consists of different resins in a state of solution, of which the most common are mastic, sandarac, lac, copal, &c.; they are prepared with either expressed or essential oils or alcohol.

VASE, (from the Latin, *vas*, a vessel,) an ornamental termination to the wall or other parts of an edifice, or to a pillar, obelisk, or the like.

Vases are made in imitation of vessels, or urns, in the form of a solid of revolution, and are often ornamented with basso-relievos in infinite variety. Those who would form a good idea, may consult the article Oval, where they will find the mathematical outlines which give the most pleasing variety to the curvature and to the general section of the solid through its axis; the ornaments, though essential decorations, are merely auxiliaries.

Vase of the Corinthian or Composite Capital, a solid of revolution, from the surface of which all the ornaments project: the section of the vase having its general outline of a form nearly similar to the surrounding contour of the leaves.

The situation of the vase is between the abacus and the astragal, at the top of the shaft, and the outline of the generating figure is concave, springing parallel to the axis, and receding gradually therefrom to the top, where it generally terminates in a fillet, also parallel to the axis.

Vases of a Theatre, were vessels under the seats used by the ancients, in order to produce greater harmony.

VAULT, (from the French *vaulte*, a cave,) an arched roof over an apartment, concave towards the void; the section may, therefore, be circular, elliptical, parabolical, hyperbolical, catenarian, cycloidal, &c., but, in general, the sections are either portions of a circle or of an ellipsis.

Vault, *Cylindric*, that of which the surface is any portion of a cylinder, never greater than the half when the axis is in the same plane with the springing of the arch. Also termed *barrel* or *wagon-headed* vault.

Vault in full Centre, that which is formed of the surface of a semicylinder.

Vault, *Surmounted*, or *Surhaussé*, that which is formed by the portion of any curve where the height is greater than half the span.

Vault, *Surbaisse*, that which is formed by the portion of any curve whose abscissa is less than the ordinate which forms half the base.

Vault, *Rampant*, that whose springing is not parallel to the horizon; such as those of the old staircases of the Louvre, and the descent into the cellars.

Vault, *Double*, a mode of construction, where one vault stands above another, in order to preserve the proportion between the exterior and interior of the building; as in St. Peter's at Rome.

Vault, *Conic*, that which forms the surface of a cone. Conic vaults may be of three kinds, according to the disposition of the axis, viz., parallel, perpendicular, or oblique to the horizon. They are seldom used in building houses; the only kind likely to come into use, is that with its axis parallel to the horizon.

Vault, *Spherical*, a vault forming the portion of the surface of a sphere; more usually called a Dome. *See* Dome.

Vault, *Annular*, that of which the plan is contained between two concentric circles: its generating section may either be that of a pointed arch, or of a semicircle, or indeed of any other curve.

Vault, *Simple*, that which is constructed of the surface of some regular solid, around one axis, or centre.

Vault, *Compound*, that which is compounded of more than one surface of the same solid, or of two different solids. Vaults of this kind are of the same solid as those whose surfaces have different axes, or different centres, as those formed of two cylinders, equal or unequal, or of two spheres, equal or unequal, penetrating each other.

VAULT, *Cylindro-cylindric*, that which is formed of the surfaces of two unequal cylinders. When their axes cut each other, they are denominated *Welsh groins.*

VAULT, *Groined*, a compound vault, which rises to the same height in its surfaces as that of two equal cylinders, or a cylinder with a cylindroid.

In the Temple of Peace, at Rome, the middle aisle is groined, all the arches are elliptic, their chord, or springing line, being that of the lesser axis: the small groins spring from mere points. The main vault of this edifice was supported by columns, which have long been removed; the entablatures, however, and the springing of the groins, still remain. The side vaulting is cylindrical, and coffered in octagons and squares. The elliptic passages of the Coliseum are groined. Groins are to be found in many Roman buildings still remaining. *See* Adams's *Ruins of Spolatro;* also the *Ruins of Balbec and Palmyra*, by Wood. The dome of the Pantheon is coffered; that of the Temple of Bacchus is plain.

The groins of Gothic edifices are numerous, and form a different class, which it would be difficult to define. The most beautiful specimens are to be found in England; and among the numerous variety, we might mention King's College, Cambridge, and King Henry the Seventh's Chapel, Westminster. *See* GOTHIC ARCHITECTURE.

A vault is an extended arch, and therefore the theory is the same as that of the arch, which has been given under the article STONE BRIDGE. The four walls of a building are strong ties to every kind of vaulting; and more particularly that of groins, where the horizontal pressure is directed against the angles, and, consequently, the four walls in this case will become ties, which ought, therefore, to be firmly built or bound together with a cast-iron bar, which will be entirely concealed. Besides what has been shown under the article STONE BRIDGE, the reader should also consult the article DOME, and the following quotation from Hutton's *Mathematics*, vol. iii., which is necessary to be understood by every engineer.

"In the practice of engineering, with respect to the erection of powder-magazines, the exterior shape is usually made like the roof of a house, having two sloping sides, forming two inclined planes, to throw off the rain, and meeting in an angle, or ridge, at the top; while the interior represents a vault, more or less extended as the occasion may require; and the shape, or transverse section, in the form of some arch, both for strength and commodious room, for placing the powder-barrels. It has been usual to make this interior curve a semicircle. But, against this shape, for such a purpose, I must enter my decided protest; as it is an arch the farthest of any from being in equilibrium in itself, and the weakest of any, by being unavoidably much thinner in one part than in others. Besides, it is constantly found, that after the centering of semicircular arches is struck, and removed, they settle at the crown, and rise up at the flanks, even with a straight horizontal form at top, and still much more so in powder-magazines with a sloping roof; which effects are exactly what might be expected from a contemplation of the true theory of arches. Now, this shrinking of the arches must be attended with other additional bad effects, by breaking the texture of the cement, after it has been in some degree dried, and also by opening the joints of the voussoirs at one end. Instead of the circular arch, therefore, we shall in this place give an investigation, founded on the true principles of equilibrium, of the only just form of the interior which is properly adapted to the usual sloped roof.

"For this purpose, put a = D K the thickness of the arch at the top, x = any abscis, D P, of the required arch A D C M, u = K R the corresponding abscis of the given exterior line K I, and y = P C = R I their equal ordinates. Then by the principles of arches, in my tracts on that subject, it is found that C I or $w = a + x - u = \text{Q} \times \frac{\dot{y}\ddot{x} - \dot{x}\ddot{y}}{\dot{y}^3}$, or $= \text{Q} \times \frac{\ddot{x}}{\dot{y}^2}$ supposing $\dot{y}$ a constant quantity, and where Q is some certain quantity to be determined hereafter. But K R or u is $= ty$, if t be put to denote the tangent of the given angle of elevation K I R, to radius 1; and then the equation is $w = a + x - ty = \frac{\text{Q}\ddot{x}}{\dot{y}^2}$.

"Now, the fluxion of the equation $w = a + x - ty$, is $\dot{w} = \dot{x} - t\dot{y}$, and the second fluxion is $\ddot{w} = \ddot{x}$; therefore, the foregoing general equation becomes $w = \frac{\text{Q}\ddot{w}}{\dot{y}^2}$; and hence $\dot{w}\dot{w} = \frac{\text{Q}\dot{w}\ddot{w}}{\dot{y}^2}$, the fluent of which gives $\dot{w}^2 = \frac{\text{Q}\dot{w}^2}{\dot{y}^2}$: but at D the value of w is $= a$, and $\dot{w} = 0$, the curve at D being parallel to K I; therefore the correct fluent is $\dot{w}^2 - a^2 = \frac{\text{Q}\dot{w}^2}{\dot{y}^2}$.

Hence, then, $\dot{y}^2 = \frac{\text{Q}\dot{w}^2}{w^2 - a^2}$, or $\dot{y} = \frac{\dot{w}\sqrt{\text{Q}}}{\sqrt{(w^2 - a^2)}}$; the correct fluent of which gives $y = \sqrt{\text{Q}} \times$ hyp. log. of $\frac{w + \sqrt{(w^2 - a^2)}}{a}$.

"Now, to determine the value of Q, we are to consider that when the vertical line C I is in the position A L or M N, then w = C I becomes = A L or M N = the given quantity, c suppose, and y = A Q or Q M = b suppose, in which position the last equation becomes $b = \sqrt{\text{Q}} \times$ hyp. log. $\frac{c + \sqrt{(c^2 - a^2)}}{a}$; and hence it is found that the value of the constant quantity $\sqrt{\text{Q}}$, is $\frac{b}{\text{h. l. } c + \sqrt{(c^2 - a^2)}}$; which being substituted for it, in the above general value of y, that value becomes

$$y = b \times \frac{\text{log. of } \frac{w + \sqrt{(w^2 - a^2)}}{a}}{\text{log. of } \frac{c + \sqrt{(c^2 - a^2)}}{a}} = b \times \frac{\text{log. of } w + \sqrt{(w^2 - a^2)} - \text{log. } a}{\text{log. of } c + \sqrt{(c^2 - a^2)} - \text{log. } a};$$

from which equation the value of the ordinate P C may always be found, to every given value of the vertical C I.

"But if, on the other hand, P C be given, to find C I, which will be the more convenient way, it may be found in the following manner: Put A = log. of a, and C = $\frac{1}{b} \times$ log. of $\frac{c + \sqrt{(c^2 - a^2)}}{a}$; then the above equation gives C y + A = log. of $w + \sqrt{(w^2 - a^2)}$; again, put n = the number whose log. is C y + A; then $n = w + \sqrt{(w^2 - a^2)}$; and hence $w = \frac{a^2 + n^2}{2n}$ = C I.

"Now, for an example in numbers, in a real case of this nature, let the foregoing figure represent a transverse verti-

cal section of a magazine arch balanced in all its parts, in which the span or width A M is 20 feet, the pitch or height D Q is 10 feet, thickness at the crown D K = 7 feet, and the angle of the ridge L K N 112° 37′, or the half of it L K D = 56° 18½′ the complement of which, or the elevation K I R, is 33° 41½′ the tangent of which is = ⅔, which will therefore be the value of t in the foregoing investigation. The values of the other letters will be as follows, *viz.* D K = a = 7; A Q = b = 10; D Q = h = 10; A L = c = $10\frac{1}{3} = \frac{31}{3}$; A = log. of 7 = .8450980; C = $\frac{1}{b}$ log. × of $\frac{c + \sqrt{(c^2 - a^2)}}{a}$ = $\frac{1}{10}$ log. of $\frac{31 + \sqrt{520}}{21}$ = $\frac{1}{10}$ log. of 2.56207 = .0408591; C y + A = .0408591 y + .8450980 = log. of n. From the general equation, then, *viz.* C I = $w = \frac{a^2 + n^2}{2n} = \frac{a^2}{2n} + \frac{1}{2}n$, by assuming y successively equal to 1, 2, 3, 4, &c., thence finding the corresponding values of C y + A or .0408591 y + .8450980, and to these, as common logs. taking out the corresponding natural numbers, which will be the values of n; then the above theorem will give the several values of w or C I, as they are here arranged in the annexed table, from which the figure of the curve is to be constructed, by thus finding so many points in it.

Value of y or C P.	Value of w or C I.
1	7.0309
2	7.1243
3	7.2806
4	7.5015
5	7.7888
6	8.1452
7	8.5737
8	9.0781
9	9.6628
10	10.3333

"Otherwise: Instead of making n the number of the log. C y + A, if we put m = the natural number of the log. C y only; then $m = \frac{w + \sqrt{(w^2 - a^2)}}{a}$, and $am - w = \sqrt{(w^2 - a^2)}$, or by squaring, &c. $a^2m^2 - 2amw + w^2 = w^2 - a^2$, and hence $w = \frac{m^2 + 1}{2m} \times a$; to which the numbers being applied, the very same conclusions result as in the foregoing calculation and table."

The following description of a method of stone-roofing in the Southern Concan, in the East Indies, was communicated to the Institution of Civil Engineers by lieutenant Outram, of the Bombay Engineers. Though hardly applicable to the climate of this country, it seems of considerable value as relating to an important part of the British Empire. The few houses which had been constructed on this plan were found to answer so well, at the time this paper was written, that government had given orders to construct, on this principle, all the public buildings, wherever suitable materials could be found.

The roofing with stone (iron-clay, or laterite) in the Southern Concan, is of a compound nature, consisting of two kinds of arches; the first being parallel to each other, from 2 to 3 feet apart, and very light, their average section being from 12 by 10 inches to 15 by 12; *i. e.* for roofs of from 25 to 35 feet span; so that when any two of these arches or ribs are complete, they are strong enough to bear slabs of stone 5 or 6 inches thick, extending a few inches over each, beginning from the wall and meeting at the top, thus forming a second complete arch, and making, with the ribs, a compound much stronger than vaulting of equal solidity over the same extent, made in the usual way.

The lateral thrust of the arches of one room are counteracted by those of the rooms on its sides, and so on for any extent; those of the end-rooms being counteracted on their outer sides by buttresses, or by the walls of baths, &c., so that the walls are required to be only sufficiently strong to support the mere weight of the masonry of the roofs, which has an average thickness of about 9 inches, excepting the plaster or tiles, and, therefore, in rooms of 400 square feet, would be about one-fifth the weight of the upper walls of a two-storied house. As the roof itself is of considerable altitude, the walls supporting it need not be of more than two-thirds the usual height.

One advantage of the lightness of these roofs is, that of whatever form the arches may be, very little *loading* will suffice; of course some arches would require no loading, but such are not the most convenient for roofs in general. The best appears to be a compound of two segments of a circle of 50° or 55°, their chords intersecting at an angle of about 100°, such compound arch requiring a little loading at the top and the haunches, which, when duly added, gives an outer surface of two inclined planes to each roof, which may be then either plastered or tiled. But instead of loading the haunches throughout with solid rubble, it is better to do so partly with hollow masonry, to the upper surface of which may be given any slopes which, by the connection of the opposite slopes of any two adjacent roofs, form a gutter of the securest kind. The average height of this gutter should be about one-third that of the roof, if to be plastered, but not so much if the roof is to be tiled.

The expense of these roofs, including the outer plaster, has been found by myself and successor, in the Concan, to be much less than that of tiled roofs over the same extent. The walls should cost no more than those of a substantial bungalow; for although the transverse walls have a greater weight to support, yet, as they need be only two-thirds the height, their total expense should not be greater than that of the walls of a substantial house. The only part of which the comparative expense remains to be considered, is the ceiling. The inner surface of the stone roofs, when finely plastered, forms an excellent ceiling; being light and cleanly, and most durable. The expense of this plastering, if not much ornamented, is below one-third that of the lath-and-plaster generally used. Hence it is plain, and has been practically found, that the total expense of stone-roofed houses in the Concan, if properly constructed, is less than that of tiled houses of the same size; but the sums saved in annual and special repairs are of far greater consideration. In the Decan, where timber is so expensive, the comparative cost of these buildings would be still less, in all those parts of it where proper stone is met with.

The principal cause of the cheapness of these stone roofs is the very little centering, &c., that is requisite. For as the ribs, or primary arches, are very light, centering of the simplest kind does for any one of them, and thus for all successively in either room. But as the centering cannot be removed from any rib till its counteracting ribs are complete, there is of course required one centering for each room, which, when one series of the primary arches is complete, may be removed with ease for the next, till a convenient number are ready for the superior arching, which of course

is very quickly formed (as before described) without any centering.

The material fittest for this kind of building are the various kinds of sand-stone, including the calcareous sand-stone of Cutch. The laterite, or iron-clay, although a good material, and the only one hitherto used, is apparently not so proper as the substance generally called free-stone, which is worked with saws, &c., and would be found to answer better than the laterite, which can be shaped only with a pickaxe, and is very heavy.

This iron-clay is found to extend from Bancoate, E. N. E., to, I believe, Ceylon, lying over the trap-rock, even on the highest Ghauts, but is very unequal in thickness and quality; that of Purnalla and Pawnghur, for instance, being of the softest and most porous kind, and that near Mahabulesher of the best. This stone, when exposed to rain, &c. becomes very hard, if good; but if taken from any depth, is so soft as to be easily cut with a knife. It is hence called *soap-stone* at Belgaum and other Madras stations.

If adopted in Europe, buildings of this kind would be as remarkable for warmth as in this country for coolness. But the plastering outside would not be advisable on account of the frost; tiles, however, or slate, would protect the roof completely.

The principal advantages of these buildings in this country are, their coolness, and the little expense incurred in annual and special repairs; indeed, the latter will never be required, if the buildings be properly constructed at first. It is also very evident, that they can never take fire, nor can white ants affect them; of course they could be built of several stories, the form of the floor-ribs being merely a small segment of a circle (or ellipse) instead of a compound of two, as in the roof. The upper floor of the jailor's house at Rutnaghery is thus built, as also part of another house.

Vault, *Reins of a*, the sides or walls which sustain the arch.

VAULTING SHAFT, the shaft which supports the ribs of a groined vault. These shafts either rise direct from the ground, or are supported upon corbels at a height above the ground; they are frequent in Romanesque and Gothic buildings.

VELLAR CUPOLA, a dome, or spherical surface, terminated by four or more walls. This kind of ceiling is frequently used over great staircases, as also over saloons, or other lofty apartments. The term is used by Alberti, vol. i. book iii., chap. 14, in the sense here defined.

VENEER, a very thin leaf of wood, of a superior quality, for covering doors, or articles of furniture, made of an inferior wood.

VENETIAN DOOR, a door lighted on each side.

Venetian Window, a window in three separate apertures, divided by slender piers, and having the centre aperture larger than the side ones. *See* Adams's *Ruins of Spolatro*, p. 26; likewise Disgodily's *Roman Antiquities*, vol. ii. *Baths of Diocletian.*

VENT, (from the French, *fente*, a small aperture,) the tube of a chimney, for conveying the smoke from the fire. The term is mostly used in Scotland. In London it is called *flue*, and in many parts of England *funnel.*

VENTIDUCTS, (from the Latin, *ventus*, wind, and *ductus*, a passage,) subterraneous places where fresh or cool air is kept, being received by proper funnels and valves.

VENTILATION, the method of supplying buildings with fresh air. In buildings which are intended for habitation, or where large bodies of persons are at any time to be congregated, it is requisite that there should be some means of replenishing the apartment with a constant supply of pure air. This necessity arises from the fact, that air, when once passed through the human system, is unfit for re-inspiration, that portion which is emitted being not only useless, but deleterious to health. On this account it becomes necessary to remove this vitiated air, and to substitute fresh air, which should be at a temperature of about 60° to 65°. The vitiated air, on being emitted from the mouth, has a temperature between 80° and 90°, and being thereby rarified and rendered lighter, has a tendency to rise to the upper part of the apartment. The method hereby naturally suggested for its removal is the provision of some means of escape at the top of the apartment; the success of this method, however, would be nullified, if the heated air, on emerging from the top of the room into a shaft intended to conduct it away, were to meet with a current of cold air, and it is therefore found necessary to heat the air in the shaft, so as to assist the upward draft. It is further necessary to keep up a constant supply of fresh air to take the place of the foul air as it is removed; this is necessary, not only for the purposes of health, but also to preserve the upward draft. In some instances, means have been adopted of forcing fresh air in with fans or bellows; but this is scarcely necessary, for if the fresh air be only allowed admission into the apartment, it will naturally enter to fill up the vacuum caused by the dispersion of the foul air. These methods, however, are seldom adopted together; sometimes the shaft, and at others the fan, is employed. Some persons contend, that the method of heating the air in the shaft does not answer the intended object, but rather causes a downward current. In supplying fresh air, it is to be observed, that cold currents of air are to be avoided: it is sometimes customary to heat the air to a certain temperature before admitting it into the apartment, the temperature being regulated according to the season of the year.

VENTILATOR, (from the Latin, *ventilo*, to fan,) a machine made to turn with the wind, and placed in the wall or roof, in order to throw a due quantity of fresh air into a close apartment.

VERGE, a small ornamental shaft in Gothic architecture.

Verge Board, same as Barge Board.

VERMICULATFD RUSTICS, stones worked to appear as if eaten by worms.

VERSED SINE, that part of the radius of a circle intercepted between the foot of the sine and the circumference, otherwise termed *sagitta*. *See* Trigonometry.

VERTEX, (Latin,) the top, generally applied to the termination of anything ending in a point; as the vertex of a pyramid, &c.

Vertex of a Conic Section, the extremity of the abscissa.

VERTICAL ANGLES, the opposite angles made by two straight lines cutting each other.

Vertical Plane, that position of a plane in which its surface is perpendicular to the horizon.

VESICA-PISCIS, a figure frequently used in the decorative part of Early English and Gothic architecture generally. It is formed by the intersection of two arcs of equal circles, and is somewhat similar in outline to that of a fish, whence its name. This form is commonly given to the auricola, or nimbus of glory, in which the representations of saints are enclosed.

VESTIBULE, a porch or entrance to any building.

VESTMENT, the hangings for an altar, or robes for the priests.

VESTRY, a building attached to a church, in which the sacred vestments and vessels were deposited; the same as Sacristy.

VIADUCT, a term applied to a roadway supported on a succession of arches.

VIGNETTE, a running ornament in Gothic mouldings.

VIGNOLA, a name commonly given to James Barozzi, or Baroggio, from the place of his birth, a small town in the duchy of Modena. He was born in 1507, and was the son of a person of consequence, whom the political strife of the day obliged to expatriate himself. James discovered an early inclination for the arts, and was sent for education to Bologna, where, from painting, to which he was first attached, he directed his attention to architecture, and by various designs, upon the principles of Vitruvius, some of which he communicated to the historian Guicciardini, he acquired an early reputation. With a view to farther improvement, he went to Rome, and, being admitted into the Academy of Design, then newly founded, was there employed in measuring the most celebrated remains of antiquity; in the prosecution of which labour he evinced uncommon taste and precision; so that the abbé Francisco Primaticcio, an able painter and architect of Bologna, who was sent to Rome in 1537 by Francis I. of France, to procure designs of the ancient buildings and casts of statues, was induced to avail himself of the assistance of Vignola, and on his return took him with him to France, where he drew plans for several eminent structures. After two years' residence in that country, Vignola returned to Bologna, and was employed in forming a plan for the façade of the church of St. Petronius, but, through the envy of his competitors, it was not executed till some years afterwards. In and near this city he built some palaces, and constructed the canal of Naviglio, running thence to Ferrara. Unduly recompensed for this work, he went to Placentia, and planned a palace for the Duke of Parma. After his return to Rome, in 1550, he built several churches there; and, through the interest of Vasari, was appointed architect to Pope Julius III., for whom he built a villa, and near it a small church, dedicated to St. Andrew, in the form of an ancient temple; and by his command he also brought the Aqua Vergine to Rome. After the death of Julius, he was employed by Cardinal Alexander Farnese in the construction of the magnificent palace, or castle, of Caprarola; and he had likewise the charge of building the church of the Jesuits at Rome, an edifice of extraordinary beauty and grandeur; but it was raised only to the cornice before the death of Vignola, and was finished by his disciple, James della Porta. After the decease of Michael Angelo, Vignola was appointed to succeed him as architect of St. Peter's, in conjunction with Piero Ligorio, a Neapolitan; which engagement, added to his advanced age, obliged him to decline an invitation from Philip II. to the court of Spain. He was, however, consulted with regard to the different plans given in for the Escurial; and one furnished by himself was highly approved, though not adopted. His other professional labours were interrupted by a commission from Gregory XIII., to settle the limits between the territories of the Church and those of the Duke of Tuscany; which he executed to the pope's satisfaction. Upon his return from this service, he was seized with a fever, and died in 1573, aged 66. His remains were solemnly interred in the church of Santa Maria della Rotunda, the ancient Pantheon.

Vignola acquired reputation as an author no less than as a practical artist. His rules for the five orders were formed on the purest taste of antiquity, and have been always reckoned classical and original. His treatise on the subject, in three volumes quarto, has been often reprinted, and translated into almost all the European languages. The French translation, with the commentaries of Daviler, is most esteemed. Vignola also wrote a treatise on practical perspective, which has passed through many editions.

VILLA, (from the Latin,) a country-house; of which the situation ought to be agreeable, commodious, and healthy, with winter and summer apartments; and surrounded with trees, to yield a cool refreshing air and shade during the heat of summer, and break the stormy cold winds of the winter. The Roman villas were very magnificent. See the description of Pliny's villas, under the article House.

VISE, a spiral staircase winding round a central newel or perpendicular shaft.

VISUAL POINT, the point of vision from which an object is viewed. *See* Point.

Visual Ray, the thread or beam of light reflected to the eye from a certain point of the object.

VITRUVIAN SCROLL a peculiar pattern of scroll-work used in classical architecture, consisting of entwined undulations.

VITRUVIUS, M. POLLIO, a very distinguished writer on architecture, is supposed to have flourished in the times of Julius Cæsar and Augustus. Of his parentage, and place of nativity, nothing certain is known: Verona and Plaisance both claim him; but the pretensions of Formiæ, now Mola de Gaëta, are more generally allowed. Of his liberal education, and his travels for information and improvement, there can be no doubt. By the exercise of his profession he had acquired some property, though perhaps not very considerable; for he says, he did not, like the generality of architects, solicit employment. Under Augustus, or perhaps one of the succeeding emperors, to whom he dedicated his works, he occupied the post of Inspector of Military Engines. But as Pliny the Elder mentions his name among other authors, in his *Natural History*, composed in the reign of Vespasian, his work must have been published before that period. Of edifices planned or constructed by him, one only is mentioned by himself, which was a basilica at Fano. His work was discovered in MS. by Poggio, in the fifteenth century, and it has ever since been held in high estimation. The ten books, into which it is distributed, not only treat on everything belonging to buildings public and private, their site, materials, forms, ornaments, conveniences, and the like; but include much of what would be termed engineering, civil and military; and even digress to geometrical problems and astronomical inventions. Besides the instruction that may be derived from it, it has afforded much important matter to the antiquary relative to the state of art and science, as well as the detail of private life, among the Romans.

Some of the most esteemed editions of Vitruvius are by Dan. Barbari, *Venet.* fol. 1567; J. de Laet, *Amst.* fol. 1649; Galiani, *Neap.* fol. 1758, with an Italian translation and notes. Claude Perrault has given a good French translation, *Paris*, fol. 1684; and we have an English one by Mr. Newton, *London*, 1791. A magnificent edition of the civil architecture of Vitruvius, in two parts, royal quarto, has been also published by W. Wilkins, Jun., A.M., F.R.S., &c. During the reign of Augustus, it does not appear that the Romans had one architect, sculptor, painter, or musician, except Vitruvius, who has given Aristoxenus's system in Latin; but he was obliged to retain the Greek *technica*, as he was the first Roman writer on the subject of music, and used Greek technical words as we do Italian. Vitruvius has described the theatrical vases used by the Greeks for the augmentation and continuation of sound, and has given a description of the organ of the ancients worked by the fall of water.

VIVO, the shaft of a column. *See* Column.

VOLUTE, one of the principal ornaments in the Ionic

capital composed of two or more spirals of the same species, having one common eye and centre, variously channelled, or hollowed out in the form of mouldings.

Among the remains of ancient architecture, the Ionic capitals of the temples of Erechtheus and Minerva Polias, at Athens, are the most beautiful. The spiral best adapted for this purpose, is known by the name of the *logarithmic spiral;* the method of describing which is as follows:

Draw a straight line for the cathetus; take any point in the straight line as a centre; through this point draw another straight line at right angles, and these two straight lines cutting each other, will form four right angles: bisect any two adjacent right angles, and let the bisecting lines be produced on the other side of the centre, and the whole will be divided into eight equal angles by as many lines, upon which the radii are to be placed.

In the calculation we are here about to make, that part of the cathetus above the centre is supposed to be 20 minutes at a medium, and the next radius 18.3; both these being given, the calculation is founded upon the following principle:

Let $a = 20$, and $b = 18.3$,

then $a : b :: b : \frac{b^2}{a}$, which gives the third radius.

$b : \frac{b^2}{a} :: \frac{b^2}{a} : \frac{b^3}{a^2}$, which gives the fourth radius.

$\frac{b^2}{a} : \frac{b^3}{a^2} :: \frac{b^3}{a^2} : \frac{b^4}{a^3}$, which gives the fifth radius.

Therefore, any radius may be found, independent of the rest: thus, $\frac{b^{x-1}}{a^{x-2}}$; x being a variable quantity, representing the numbers of the radius. Thus, suppose the eighth radius were required; make $x = 8$, then $\frac{b^{x-1}}{a^{x-2}} = \frac{b^7}{a^6}$.

The arithmetical operation will be best performed by logarithms: now, as $b = 18.3$, and $a = 20$, multiply the logarithm of 18.3 by 7, and the logarithm of 20 by 6, subtract the latter product from the former, and the remainder will be the logarithm of the answer.

Now the logarithm of 18.3 is 1.26245, which, multiplied by 7, gives 8.83715: and the logarithm of 20 is 1.30103; which, multiplied by 6, gives 7.80618: then 8.83715 — 7.80618 = 1.03097, which is the eighth radius.

The following method will serve to prove the result of the operations, which are all dependent on each other; and will save the trouble of frequent reference to the Logarithmic Tables.

Log. 20 = 1.301030

log. 18.3 = 1.262451
1.262451
2.524902
1.301030
1.223872, the corresponding number is 16.74, which is the third radius.

Log. 18.3 = 1.262451

log. 16.74 = 1.223872
2
2.447744
1.262451
1.185293 = log. 15.32, 4th radius.

Log. 16.74 = 1.223872

log. 15.32 = 1.185293
2
2.370586
1.223872
1.146714 = log. 14.01, 5th radius.

Log. 15.32 = 1.185293

log. 14.01 = 1.146714
2
2.293428
1.185293
1.108135 = log. 12.82, 6th radius.

Log. 14.01 = 1.146714

log. 12.82 = 1.108135
2
2.216270
1.146714
1.069556 = log. 11.73, 7th radius.

Log. 12.82 = 1.108135

log. 11.73 = 1.069556
2
2.139112
1.108135
1.030977 = log. 10.73, 8th radius.

Log. 11.73 = 1.069556

log. 10.73 = 1.030977
2
2.061954
1.069556
.992398 = log. 9.82, 9th radius.

And thus, having gone through one revolution, the radii of the remaining revolutions may be found in a similar manner.

Now to apply the number thus found:

Plate I.—The centre is marked by the point ⊙; upon the cathetus set 20 from ⊙ upwards, which will give the extremity of the first radius; upon the second radius towards the left, set 18.3 from the centre, which will give another point in the curve; then, following round in the same progression, from the centre, set 16.74, 15.32, 14.01, 12.82, 11.73, 10.73, 9.82, &c. upon each succeeding radius respectively, to 2.37, and three points will be found in each quadrant.

In the Plate here referred to, we have only retained one

decimal place, the scale not admitting of any more. And note, when the second decimal is 5, or more, the first decimal is made one more.

In the first quadrant, take the length of the middle radius, *viz.* 18.3: set one foot of the compasses in 20, then describe an arc near to the centre; with the same radius set the foot of the compasses in 16.7, and describe an arc cutting the former; then, from the point of intersection, as a centre, describe an arc through all the three points 20, 18.3, 16.7. Proceed in the same manner with every quadrant, by taking the middle radius; and from the extremity of each outer radius, describe two arcs intersecting each other; and from the point of intersection, as a centre, with the same radius describe an arc through the two extremities, until you arrive at 2.4; then with radius 2.4 describe a circle for the eye, and the whole spiral will be completed.

Should it be required to describe a spiral through any given point, so as to form a fillet, divide the distance from the centre to that point into twenty equal parts, form a new scale, and proceed in the manner already described.

The foregoing Table contains the lengths of all the radii, to three places of decimals, and will be of use for volutes upon a large scale. And instead of constructing a scale for every different spiral, the sector may be used, which is an universal scale to any distance within its reach.

But no instrument can be more easily or more accurately applied, than the proportional compasses; for if the slider be so shifted, that the two long legs may be to the two short legs in the ratio of the two first radii, then all the remaining radii may be found by extending the points of the long legs to the shortest radius, which will give the length of the next shorter radius between the points of the short legs; and by proceeding in this manner till all the points are found, the curve may be drawn as before directed.

Plate II.—A volute drawn according to the preceding principles, consisting of three spirals; the numbers affixed round the outer spiral are supposed to be minutes, and consequently no other scale will be required than that of the order itself; but in drawing the two interior spirals, two new scales must be formed; or the scale of the order might be made to answer the purpose, by setting the proportional compasses in the ratio of the two radii, then taking the length of the radii from the scale with the long legs, and transferring the distances between the short legs to the spiral, and drawing the curve; so that the whole may be completed as before.

The volute in this Plate is similar to that of the Ionic temple at Athens, the temple of Bacchus at Teos, and that of Minerva Polias at Priene in Ionia.

Plate III. *Figure* 1.—A volute in imitation of that of the temple of Erechtheus, at Athens, drawn according to the preceding principles. It consists of eleven spirals, which may be all drawn from the scale of the order by the assistance of a pair of proportional compasses. But if this useful instrument is not in the hands of the delineator, the eleven scales are here exhibited at *Figure* 2, for drawing the same number of spirals.

An universal scale may be made, as in *Figure* 3, thus: describe an equilateral triangle, C A B, upon C B, equal to the greatest radius; divide C B into twenty equal parts, and draw straight lines from the points of division to A; produce C B to *b*, and make B *b* equal to one of the equal parts; divide B *b* into ten equal parts, and draw lines to A; then make A D and A E each equal to the first radius, and draw the line E D, which produce to meet A *b* at *d*; then E D *d* will give the scale for drawing the spiral required: E D being the scale of units, and D *d* that of tenths; and thus any other radius may be divided at once.

Figure 4, is another method of obtaining an universal scale, by means of a right-angled triangle, A B C, right-angled at C, making C B and C A equal to each other: but there is no method so exact and expeditious as the proportional compasses, and one scale, which may either be that of the order or not, and consequently any scale divided into units and tenths will answer the purpose, if this instrument be used.

Plate IV. shows a design for the capital and base of an Ionic column, with the details of capital and volute.

Figure 1.—Front view of the capital.

Figure 2.—Plan of the same.

Figure 3.—Profile or section through the front.

Figure 4.—Section through the flank.

Figures 5, 6, and 7.—Parts of the capital enlarged.

Figure 5.—Half of the front, showing the sections through the volute and through the front.

Figure 6.—Elevation of the flank.

Figure 7.—Section through the front.

Figure 8.—Elevation of the base of the column to the same scale as *Figure* 1.

VOUSSOIRS, the wedge-shaped stones forming the curvature or intrados of an arch.

W.

WAGGON-HEADED ceiling, a semi-cylindrical, or barrel-ceiling, not uncommon in churches of the Gothic style.

WAINSCOT, (from the Dutch *wayschot*,) in joinery, the lining of walls, constructed of wood, and most generally panelled.

The term *wainscoting*, as applied to the lining of walls, originated in a species of foreign oak of the same name, used for that purpose; and although that has long been superseded by the introduction of fir-timber, the term has been continued notwithstanding the change of the material.

Wainscoting is generally used for the lining of walls to the height of about 5 or 6 feet; and when it does not reach the whole height, it is called *dwarf wainscoting*.

To prevent the joints of panels from opening in consequence of the glue being softened or consumed by damps from the walls, the back of the wainscot ought to be primed over at the joint with white lead, or Spanish brown, and linseed oil.

The method of measuring wainscot is, to multiply the length by the breadth, and find the number of square yards; the price is adjusted according to the difficulty of the work, or the time required to perform it. *See* CARPENTRY and JOINERY.

WALL-PLATE, a piece of timber placed in or upon a wall to receive the ends of joists or rafters.

WALLS, (perhaps from the Latin *vallum*, a fence,) those masses of materials which generally have their faces in vertical or plumb-lines; or, at least are so disposed, that a plumb-line from any point in either surface will fall entirely within the surface, or within the thickness of the wall.

In walls constructed for shelter, if the materials cannot be joined without interstices, those interstices ought to be so closed as to render the work impervious to rain or drift.

The materials with which walls are generally constructed are brick or stone. Some walls may be built either of rough or squared stones. When the exterior walls of dwelling-houses are to be constructed of rough stone, the stones ought to be laid in mortar; but when they are squared and smoothed, this is not necessary. The ancients, in building their edifices with squared stones, seldom laid them in mortar; but their joints and beds were so exactly wrought, as to come nearly in contact with each other. *See* STONE WALLS.

As bricks cannot be formed so regularly as stones, on account of the burning, they are usually laid in mortar. *See* BRICKLAYING and BRICKWORK.

From the definition given of a wall, founded upon the axiom, that every material which overhangs has a tendency to fall, or to break off, or to overturn the structure of which it is a part, it is evident, that as a wall rises it ought either to diminish in its thickness, or to follow the plumb-line.

Walls common to two apartments are called *partition walls*, or simply *partitions*. When a wall is divided or separated by ornaments, apertures, or projections, it is said to be *intermitted;* but if uninterrupted, it is called *a continued wall.* It is, however, generally understood, that when a wall has apertures without projections, as columns and pilasters, it is said to be *continued*, which is contradictory to the common acceptation of the term.

WALLS, *Abutments in*, the beds that are prepared for the springing of an arch.

WALLS, *Cased*, those that are faced up anew all round the building, in order to cover an inferior material, or old work gone to decay.

WALLS, *Emplecton*, those which are built in regular courses, with the stones smoothed in the face of the work: they are of two kinds, Roman or Grecian. The difference is, that the core of the Roman emplecton is rubble; whereas in the Grecian it is built in the same manner as the face, and every alternate stone goes through the entire thickness of the wall.

WALLS, *Isodomum*, those where the courses are of equal thickness, compact, and regularly built; but the stones are not smoothed on the face.

WALLS, *Pseudo-isodomum*, those which have unequal courses.

For other particulars respecting walls, *see* the articles above referred to; also BUILDING, PISE, and MENSURATION.

WATER-CLOSET, an apartment so generally known as to render any definition of it unnecessary. There are no good houses without one or more of them. Their construction belongs entirely to the engineer: the chief thing which the architect has to attend to is, to place his water-closets in such a situation as to be isolated from the principal apartments, to conceal them from general observation, and to make them as accessible as possible. The number of water-closets in a house ought to be in proportion to the magnitude of the building; in large mansions, a certain number of water-closets must be appropriated to the servants, as well as to the family itself. One of the principal things which the architect must attend to is, to prevent all recoil or return of noxious effluvia.

WATER SHOOT, a wooden trough for discharging rain-water from a building.

WATER TABLE, the upper surface of a coping, or projection, where the superior part of a wall recedes from the inferior or lower part.

Water tables are frequently used in edifices of the pointed style, particularly near the base of the building: as in buttresses consisting of several stages, where the sloping parts, which cover the solids below, are called *water-tables.*

WAY-WISER. *See* PERAMBULATOR.

WEATHER BOARDING, signifies the nailing up of boards lapped upon each other, so as to prevent rain or drift from passing through. For this purpose, the boards are generally made thinner on one edge than on the other; particularly when the work is intended to be permanent: the boards thus formed are called *feather-edged boards.* In using feather-edged boards, the thick edge of the upper board is laid upon the thin edge of the board below, about an inch over, or, in very secure work, an inch and a half, the nails being driven through the lap.

WEATHERING, a slight inclination given to copings or ledges of walls, for the purpose of throwing off the rain.

WEATHER MOULDING, a moulding carried over a door or window, for the purpose of diverting rain-water from the parts beneath; otherwise termed *drip-stone*, or *label.*

WEATHER TILING, the covering of an upright or wall with tiles.

WEDGE, (from the Danish *wegge.*) Writers on mechanics, in treating of the wedge, have frequently drawn false conclusions respecting the proportion which exists between the impelling power applied to the head, and the resisting powers opposed to the sides; and those conclusions have resulted from false opinions concerning the directions of the resisting powers.

It is evident, that when wood or other substance is split by a wedge which does not fill the cleft, that is, when the angle of the cleft is more acute than that of the wedge, the power or action of each side of the wedge, equal and opposite to the resistance of the cleft, must be resolved into two; the one in the direction of the side of the cleft, which tends to thrust it forward; and the other perpendicular to that direction, which tends to tear it asunder. It is by not attending to the above solution, that writers on this subject have been led into mistakes; for, instead of considering the powers which act in those two directions, they have imagined a single power only as acting obliquely on each side. But if the sides of the wedge are perfectly polished, as we must here consider them, no single permanent power can be applied to impel any one of them, unless its direction be perpendicular to the plane of the side to which it is applied; therefore, two oblique powers, applied on opposite sides of the same point, are at least necessary to sustain each other and the action of the plane; and in the case of the wedge above mentioned, the directions of those two oblique powers will always be perpendicular to each other, as will appear obvious from the two following Propositions.

PROPOSITION I. *Figure* 1.—Let A B C be a vertical section passing through the centre and at right angles to the head and sides of any isosceles wedge; also in the plane of this section, and at right angles to its sides, A B, B C, and C A, let three powers be applied, such, that their directions may all mutually intersect in the axis, and their efforts sustain the wedge in equilibrio; which three powers are as A B, B C, and C A, respectively.

Let L M, K I, E D be the directions of these three powers,

which, produced, intersect each other and the axis in O. Since, by hypothesis, these three powers directed to the same point are in equilibrio, and the three sides of the triangle A B C are at right angles to their directions; therefore, by a well-known statical principle, the intensities of these two powers are as A B, B C, and C A respectively.

PROPOSITION II.—When an impelling power applied to the head of an isosceles wedge is in equilibrio with the resisting power of a cleft, the angle of which is more acute than that of the wedge inserted, then, universally,

The impelling power applied to the head,

The action of the wedge on either side of the cleft,

The part thereof which tends to thrust it forward,

And the remaining part, which tends to tear it asunder,

Are

As twice the sine of half the vertical angle of the wedge,

The radius,

The sine of the angle contained by the sides of the wedge and cleft,

And the cosine of that angle, respectively; the same radius being common.

Figure 2.—Let A B C represent a vertical section of the wedge and cleft, similar in position to that described in Proposition I.; also let the two sides of the cleft D H, D H, be equal, and in contact with the sides of the wedge A C, A C, at equal distances, D C, D C, from the vertex C, in which case the sides of the wedge make equal angles with those of the cleft. Through either point D, draw D F, at right angles, and equal to A C; also through D draw D E, at right angles to D H, and complete the parallelogram D E F G. Then, by Proposition I. the line A A represents in quantity the impelling power applied to the head, and the line D F represents in quantity and direction the whole action of the side of the wedge on that of the cleft, which, by hypothesis, is balanced by its resistance; but the power D F is resolved into two, represented in quantity and direction by D G, D E, respectively: the one, being in the direction of the cleft, tends to thrust it forward; and the other, being at right angles thereto, tends to tear it asunder,

Therefore the powers mentioned in the Proposition are as A A, D F, D G, and D E, respectively; but as A C=D F, being radius, these lines are respectively equal to

Twice the sine of half the vertical angle of the wedge,

The radius,

The sine of the angle contained by the sides of the wedge and cleft,

And the cosine of that angle. Hence the proposition is manifest.

WEIGHT, in mechanics, denotes anything to be raised, sustained, or moved, by a machine, as distinguished from the power, or that by which the machine is put in motion.

WEIGHT, in commerce, denotes a body of a known weight, appointed by law to be the standard of comparison between different quantities of merchandise of certain descriptions; the weight itself being usually of lead, iron, brass, or other metal.

The great diversity of weights and measures, in all nations, for different kinds of commodities, has always been a just subject of regret and complaint; being the cause of various disputes and deceptions, which it is almost impossible to avoid under present circumstances. And it is therefore much to be wished, though perhaps little to be expected, that one uniform system of weights should be adopted as applicable to all kinds of substances; an attempt at which was made in France during the revolution, but which was afterwards laid aside by an imperial decree, in consequence of the repeated remonstrances of people in trade; so difficult is it to overcome prejudices and customs long established, however advantageous the change may be when properly understood.

In the reign of king Richard I. it was ordained, that there should be only one weight and one measure throughout England; and in the *Phil. Trans.* No. 458, p. 457, we find an account of the analogy between English weights and measures drawn up by Mr. Barlow; in which he states, that anciently the cubic foot of water was assumed as a general standard for all liquids. This cubic foot, of 62½ lb. multiplied by 32, gives 2000 lb. the weight of a ton; and hence 8 cubic feet of water made a hogshead, and 4 hogsheads a tun, or ton, in capacity and denomination, as well as weight.

Dry measures were raised on the same model. A bushel of wheat, assumed as a general standard for all sorts of grain, also weighed 62½ lb. Eight of these bushels make a quarter; and 4 quarters, or 32 bushels, a ton. Coals were likewise sold by the chaldron, supposed to weigh a ton, or 2000 lb., though in reality it probably weighs upwards of 3000 lb.

This principle, though not sufficiently accurate in some cases, was extremely obvious, and might have been improved so as to answer all the purposes of commerce; but unfortunately, instead of rendering it more simple, it has been made infinitely more complicated by the different weights since introduced.

Modern European Weights.—1. English weights. By the twenty-seventh chapter of *Magna Charta*, the weights all over England are to be the same; but for different commodities there are two different sorts, viz.: Troy weight and Avoirdupois weight. The origin from which they are both raised is, a grain of wheat gathered in the middle of the ear.

In Troy weight, 24 of these grains make 1 pennyweight sterling; 20 pennyweights make 1 ounce; and 12 ounces 1 pound.

By this weight we weigh gold, silver, jewels, and liquors. The apothecaries also use the Troy pound, ounce, and grain: but they divide the ounce into 8 drachms, the drachm into 3 scruples, and the scruple into 20 grains.

In Avoirdupois weight, the pound contains 16 ounces, but the ounce is less by near one-twelfth than the Troy ounce; this latter containing 480 grains, and the former only 437½. The ounce contains 16 drachms; 80 ounces Avoirdupois are only equal to 73 ounces Troy; and 17 pounds Troy are equal to 14 pounds Avoirdupois.

By Avoirdupois weight are weighed meat, grocery wares, base metals, wool, tallow, hemp, drugs, bread, &c.

Comparison between Troy and Avoirdupois Weight.

175 Troy pounds are equal to 144 Avoirdupois pounds.

175 Troy ounces are equal to 192 Avoirdupois ounces.

1 Troy pound contains 5760 grains.

1 Avoirdupois pound contains 7000 grains.

1 Avoirdupois ounce contains 437½ grains.

1 Avoirdupois drachm contains 27.84375 grains.

1 Troy pound contains 13 ounces, 2.651428576 drachms Avoirdupois.

1 Avoirdupois pound contains 1 lb. 2 oz. 11 dwts. 16 gr. Troy.

Therefore the Avoirdupois lb. is to the lb. Troy as 175 to 144, and the Avoirdupois oz. is to the Troy oz. as 437½ to 480.

Goldsmiths, jewellers, &c., have a particular class of weights, viz.: for gold and precious stones, the carat and grain; and for silver, the pennyweight and grain. In the mint, they have also a peculiar subdivision of the Troy grain: thus dividing

the grain into 20 mites,
the mite into 24 droits,
the droit into 20 periots,
the periot into 54 blanks.

The dealers in wool have likewise a particular set of weights, viz.: the sack, weigh, tod, stone, and clove; the proportions of which are as follow:

the sack contains 2 weighs,
the weigh 6½ tods,
the tod 2 stones,
the stone 2 cloves,
the clove 7 pounds.

Also 12 sacks make a last, or 4368 pounds.

Farther,

56 lb. of old hay, or 60 lb. new hay, make a truss.
40 lb. of straw make a truss.
36 trusses make a load of hay or straw.
14 lb. make a stone.
5 lb. of glass a stone.

Other nations have also certain weights peculiar to themselves: thus, Spain has its arrobas, containing 25 Spanish pounds, or one-fourth of the common quintal: its quintal macho, containing 150 pounds, or one-half of the common quintal, or 6 arrobas; its adarme, containing one-sixteenth of its ounce. And for gold, it has its castillan, or one-hundredth of a pound; and its tomin, containing 12 grains, or one-eighth of a castillan. The same are in use in the Spanish West Indies.

Portugal has its arroba, containing 32 Lisbon arratals, or pounds. Savary also mentions its faratelle, containing 2 Lisbon pounds; and its rottolis, containing about 12 pounds. And for gold, its chego, containing 4 carats. The same are used in the Portuguese East Indies.

Italy, and particularly Venice, have their migliaro, containing 4 mirres; the mirre containing 30 Venice pounds; the saggio, containing a sixth part of an ounce. Genoa has five kinds of weights, viz.: large weights, whereby all merchandizes are weighed at the custom-houses; cash weights for piasters, and other specie; the cantara, or quintal, for the coarsest commodities; the large balance for raw silks, and the small balance for the fine commodities. Sicily has its rottolo, equal to 32½ pounds of Messina.

Germany, Flanders, Holland, the Hanse-towns, Sweden, Denmark, Poland, &c., have their schippondt, which, at Antwerp and Hamburgh, is 300 pounds; at Lubeck, 320; and at Konigsberg, 400 pounds. In Sweden the schippondt for copper is 320 pounds; and the schippondt for provisions 400 pounds. At Riga and Revel, the schippondt is 400 pounds; at Dantzic, 340 pounds; in Norway, 300 pounds; at Amsterdam, 300, containing 20 lysponts, each weighing 15 pounds. In Moscow they weigh their large commodities by the bercheroct, or berkewits, containing 400 of their pounds. They have also the poet, or poede, containing 40 pounds, or one-tenth of the bercheroct.

In order to show the proportion of the several weights used throughout Europe, we shall add a reduction of them to one standard, viz.: the London pound.

Proportion of the Weights of the principal Places in Europe.

The 100 lb. of England, Scotland, and Ireland, are equal to

lb.	oz.	
91	8	of Amsterdam, Paris, &c.
96	8	of Antwerp or Brabant.
88	0	of Rouen, the viscounty weight.
106	0	of Lyons, the city weight.
90	9	of Rochelle.
107	11	of Toulouse and Upper Languedoc
113	0	of Marseilles or Provence.
81	7	of Geneva.
93	5	of Hamburgh.
89	7	of Frankfort, &c.
96	1	of Leipsic, &c.
137	4	of Genoa.
132	11	of Leghorn.
153	11	of Milan.
152	0	of Venice.
154	10	of Naples.
97	0	of Seville, Cadiz, &c.
104	13	of Portugal.
96	5	of Liege.
112	0⅔	of Russia.
107	0 1/24	of Sweden.
89	0½	of Denmark.

Proportion of the Weights of several Places in Europe compared with those of Amsterdam.

The 100 lb. of Amsterdam, are equal to

lb.	
105	of Antwerp.
100	of Bayonne and Paris.
95¼	of Bergen in Norway.
151	of Bologna.
103	of Bremen.
125	of Breslaw.
105	of Cadiz.
107	of Copenhagen.
97	of Dublin and Edinburgh.
109	of London.
114	of Madrid.
169	of Naples.
109	of Riga.
146	of Rome.
110	of Stettin.
182	of Venice.

Comparison of English and Foreign Weights.

ENGLISH WEIGHTS.

Troy Weight.

lb.	oz.	scrup.	drs.	grains.	grammes
1 =	12 =	96 =	283 =	5760 =	372.96
1 =	8 =	24 =	480 =	31.08	
1 =	3 =	60 =	3.885		
1 =	20 =	1.395			
1 =	0.06475				

Avoirdupois Weight.

lb.	oz.	drs.	grains.	grammes.
1 =	16 =	256 =	7000	= 453.25
1 =	16 =	437.5	= 28.32	
1 =	27.975	= 1.81		

GERMAN.

71 lb. or grs. English Troy = 74 lb. or grs. German apothecaries' weight.
1 oz. Nuremburg, medic. weight = 7 dr. 2 scru. 9 grains English.
1 mark Cologne = 7 oz. 2 dwt. 4 gr. English Troy.

DUTCH.

1 lb. Dutch = 1 lb. 3 oz. 16 dwt. 7 gr. English Troy.
787½ lb. Dutch = 1038 lb. English Troy.

Swedish Weights, used by Bergman and Scheele.

The Swedish pound, which is divided like the English apothecary's, or Troy pound, weighs 6556 grains Troy.

The kanne of pure water, according to Bergman, weighs 42250 Swedish grains, and occupies 100 Swedish cubic inches. Hence the kanne of pure water weighs 48088.719444 English Troy grains, or is equal to 189.9413 English cubic inches; and the Swedish longitudinal inch is equal to 1.238435 English longitudinal inch.

From these data the following rules are deduced:—

1. To reduce Swedish longitudinal inches to English, multiply by 1.2384, or divide by 0.80747.

2. To reduce Swedish to English cubic inches, multiply by 1.9, or divide by 0.5265.

3. To reduce the Swedish pound, ounce, drachm, scruple, or grain, to the corresponding English Troy denomination, multiply by 1.1382, or divide by 0.8786.

4. To reduce the Swedish kannes to English wine pints, multiply by 0.1520207, or divide by 6.57804.

5. The lod, a weight sometimes used by Bergman, is the 32d part of the Swedish pound: therefore, to reduce it to the English Troy pound, multiply by .03557, or divide by 28.1156.

Correspondence of English Weights with those used in France before the Revolution.

The Paris pound (poids de marc of Charlemagne) contains 9216 Paris grains: it is divided into 16 ounces, each ounce into 8 gros, and each gros into 72 grains. It is equal to 7561 English Troy grains.

The English Troy pound of 12 ounces contains 5760 English Troy grains, and is equal to 7021 Paris grains.

The English Avoirdupois pound, of 16 ounces, contains 7000 English Troy grains, and is equal to 8538 Paris grains.

To reduce Paris grains to English Troy grains, divide by	1.2189
To reduce English Troy grains to Paris grains, multiply by	
To reduce Paris ounces to English Troy, divide by	1.015734
To reduce English Troy ounces to Paris, multiply by	

Or the conversion may be made by means of the following tables

I. *To reduce French to English Troy Weight.*

The Paris pound	=	7561	English Troy grains.
The ounce	=	472.5625	
The gros	=	59.0703	
The grain	=	.8204	

II. *To reduce English Troy to Paris Weight.*

The English Troy lb. of 12 oz.	=	7021.	Paris grains.
The Troy ounce	=	585.0893	
The drachm of 60 grains	=	73.1354	
The dwt. or dernier of 24 grains	=	29.2541	
The scruple of 20 grains	=	24.3784	
The grain	=	1.2189	

III. *To reduce English Avoirdupois to Paris Weight.*

The Avoirdupois lb. of 16 oz. or 7000 Troy grains	=	8538	Paris grs
The ounce	=	533.6250	

The following is a Table of Weights, according to the new French system:

Names.	French value.	English value.
Millier	1000 kilogrammes = 1 French ton ..... =	19.7 cwts.
Quintal	100 kilogrammes .. =	1.97 cwts.
Kilogramme...	Weight of one cubic decimeter of water of the temperature of 39° 12′ Fahrenheit	2.6803 lbs. troy. 2.5055 lbs. avoir.
Hectogramme $\frac{1}{10}$th of kilogramme... =		3.2 ozs. troy. 3.52 ozs. avoir.
Decagramme $\frac{1}{100}$th of kilogramme .. =		6.43 dwts. troy.
Gramme.... $\frac{1}{1000}$th of kilogramme.. =		15.438 grs. troy. 0.643 dwt. 0.032 ounce troy
Decigramme $\frac{1}{10000}$ of kilogramme .. =		1.5438 grains troy.

See also the article MEASURE.

WEIGHTS OF A SASH, two weights by which the sash is suspended, and kept steady in any situation it is put into, by means of cords passing over pulleys. The two vertical sides of the sash-frame are generally made hollow, in order to receive the weights, which by this means are entirely concealed: and thus, to keep the sash in suspension, each weight must be exactly half the weight of the sash. The cords must be of the best quality, otherwise they will soon fret to pieces.

WEIR, a dam placed across a river or stream, for the purpose of ponding back a portion of the water.

WELCH-GROINS, those formed by the intersection of two semi-cylindrical vaults, one of which is of less height then the other.

WELDING, the method of joining two pieces of metal by means of heat, by which they are brought nearly to a state of fusion.

WELL-HOLE, in building, a term differently understood by workmen and writers: by some, the whole space enclosed by the walls of a staircase is called the *well-hole;* by others, it is used only for the space left in the middle at the ends of the steps in a geometrical staircase. In strict propriety, the whole apartment in which the stairs are placed ought to be called *the well;* and the void formed by the ends of the steps *the well-hole.*

WHEEL, (from the Saxon, *wheol,*) in mechanics, an engine consisting of a circular body turning on an axis, for enabling a given power to overcome or move a given weight or resistance. This machine may be referred entirely to the LEVER, which see.

WHEEL-WINDOW, a circular window, common in Lombardic and Gothic buildings; otherwise termed a ROSE or CATHERINE-WHEEL window.

WHETSTONE, a stone of a very fine quality, by which tools for cutting wood are brought to a fine edge, after being ground upon a grit-stone, or grinding-stone, to a rough edge.

WICKET, (from the Dutch,) a small door made in a gate

WIND BEAM, an obsolete name for a COLLAR BEAM: *see* that article.

WINDERS, those stairs by which, in a continuous flight, the direction of ascent is changed, the risers being disposed as radii of a circle, and the treads in consequence being narrower at one end than the other; the width of the treads at the centre should be the same as that of the *flyers.* *See* STAIRS.

WINDING-STAIRS, those which wind round a central newel, or a circular well-hole. *See* STAIRS.

WINDLASS, or WINDLACE, a machine for raising weights, n which a cope or chain is wound about a cylindrical body, moved by several levers.

Also a handle, by which anything is turned.

WINDOWS, (from the Danish, *vindue*, or the Welsh *wynt dor*, a passage for the wind,) those apertures in walls through which light is transmitted to the interior of buildings.

Windows are generally of a rectangular form, the sides, or jambs, being vertical, and the bottom and lintel horizontal. Semicircular windows have a very elegant effect, particularly in circular buildings, as was generally the practice of the Romans; but those that are finished with segments, or semi-ellipses, are not so beautiful; and much less so are such as are constructed of entire circles or ellipses, for which, few or no precedents are to be found in the buildings of the ancients.

Windows must be proportioned in height and width to the principal rooms. The dressings of windows are the sill, and the insisting architrave, surrounding the upper part, crowned by a cornice and frieze. The breadth of the architrave may be one-sixth of that of the aperture; the frieze the same; the height of the cornice will depend upon the number of mouldings.

Windows should be so placed with respect to the principal room, or dining and drawing-rooms, as to be equally distant from each end of the apartment, and equidistantly distributed in the principal front, of one size, with their edges or sides in the same vertical lines. This adjustment will frequently be attended with difficulties; and to accommodate the principle, an alteration of the proportions, in a small degree, will sometimes be necessary. In houses of the middle class, where economy is an equal consideration with elegance or beauty, the windows frequently reach as high as the cornice, or even so high as to cut the cornice, wholly, or in part; a mutilation that destroys the beauty of the finishing. In such cases, it would be better to have more lofty stories, or lower windows. In large edifices, where proportions are considered, the spaces above the windows are more ample, and allow a more elegant finish, with a greater repose for the eye. Further particulars respecting windows will be found under APARTMENT, BUILDING, CASEMENT, HOUSE, JOINERY, SASH-FRAME, and SKYLIGHT. *See* also TRACERY, and GOTHIC ARCHITECTURE, &c.

Plate 1. *Figure* 1.—A window finished in the usual manner. No. 1. The elevation. No. 2. The flank.

Figure 2. The elevation of a window, where, the thickness of the wall not being sufficient to allow of boxings, the shutters are hinged upon a hanging style.

Figure 3.—The section of the foregoing.

Figure 4.—Section and plan of the sash-frame and shutters of a window, showing the same finishing, whether the shutters be folded in their boxings to admit light, or extended to their breadth upon the sashes to exclude it.

Figure 5.—Plan and section of the lower sash shutters and boxings of a common window, showing the nature of the work.

WINDOW-SHUTTERS, the wooden doors by which windows are occasionally closed, or secured. *See* BOXINGS, JOINERY, and SASH-FRAME.

WING, the outlying and returning ends of a building.

WITHS, (from the Saxon,) the partitions of flues. *See* CHIMNEY.

WOOD, (from the Saxon *wude*,) a fibrous material, of the greatest use in building, formed into shape by edge-tools. For a description of the different kinds of wood as applicable to building, see the articles TIMBER and MATERIAL; and for the method of measuring it, *see* MENSURATION, towards the end. *See* also SEASONING OF TIMBER, and STRENGTH OF MATERIALS.

WOOD BRICKS, blocks of wood cut to the form and size of bricks, inserted in the interior walls of apartments, as holds for the joinery.

WOODEN BRIDGES, are platforms constructed of carpentry, for crossing streams, rivers, roads, &c. These bridges may be looked upon as the origin of all such constructions, whether of stone, wood, or iron. In early times it may fairly be supposed, that trees, or planks made from them, would be thrown from one bank of the stream to the other, so as to serve for a footway, by which a passage might be effected. This might have been suggested in the first instance by accident, either by a tree falling in that position, or else by its growing across a stream, as sometimes happens with willows, &c. A plank placed from one bank of a stream to another, is the simplest form of a timber bridge; it is at the same time the most perfect; and the principle on which it is suspended, or kept in its proper position, is worthy of consideration, for we may learn how to construct the best and most advantageous kind of bridge, suitable for immense spans, from this unpretending, and apparently unpremeditated contrivance.

When a strong plank is thus laid upon two supports, that part of it which lies midway between them, has to sustain its own weight, together with the transit load which it has to bear, such as that of anything crossing over it, by the cohesion between its particles, for as that part of the plank has nothing to rest upon, it is therefore clear, that it has a tendency to break somewhere between the points of support when the strain becomes very great upon it; but owing to this cohesion of the particles, which attracts them to one another, such a plank cannot snap asunder, because the fibres of the timber of which it is formed, are so interwoven, that one particle or atom of the material will not readily be separated from its fellow, as long as such material remains in a sound state. This being the case, the effect of the weight upon the beam will cause it to bend, or what is technically termed, to sag, but in order to this, it will be necessary that the fibres on the under side of the beam should first be drawn out, or lengthened, that is, subjected to a tensile strain, while on the contrary, those on the upper surface will be forced to contract, or become shorter, in other words, they will be pressed upon longitudinally, and thus be subjected to a compressive force. It is also evident, that there must be some intermediate plane between the upper and lower surfaces of the beam, where the two opposite contending forces will meet, in which, of course, neither will preponderate; this, which is denominated the neutral plane, is situated lower or higher, according to the depth of the beam, the homogeneity and cohesion of the material of which it is composed, and a variety of other considerations. As a general formula for finding the weight with which it would be advisable to load such a beam, we may give the following,

$$w = \frac{2\,b\,d^2 s}{3\,l}$$ where w is the weight in lbs. with which the beam may be loaded, including that of the beam itself, b its breadth in inches, d its depth in inches, l its length in inches and s some known constant, representing the calculated strength of the kind of timber, or other material, employed. That of larch has been estimated at 280, Riga fir at 376, English oak 400, Mar Forest fir 415, red pine 447, pitch pine 544, Canadian oak 588, ash 675, teak 820. When the inertia of such a bridge is small, the deflection, or sagging, of the beam is found to depend upon a

certain quantity, which varies directly as the square of its length, and inversely as the product of the central statical deflection, (that is, the amount of deflection which would take place if all the load were placed at the centre of the beam,) and with the square of the velocity with which the load passes over the bridge.

In a bridge, therefore, constructed with a single beam, there are two counteracting forces, which, by mutually neutralizing each other, prevent the beam of which it consists from yielding; this constitutes what is called the rigidity of the timber, which thus opposes an obstacle to its bending, and which is increased in the direct proportion of the square of the depth and inversely as its length within certain limits, provided it is not loaded to more than a third of its calculated capability, which is taken into consideration in the above formula. This form of bridge merely rests upon its abutments, or piers, pressing vertically upon them. It exerts no force tending to overturn or push against them in an oblique direction. In this consists its superiority over bridges which are constructed solely on the principle of compression, such as arched bridges in general, or bridges formed completely on the principles of tension, as in the case of suspended bridges, in both of which it is necessary to introduce some countervailing weight or pressure, so as to resist the tendency which both those descriptions of bridges have of oversetting their supports. This adds greatly to their complicated nature, and consequently to the difficulty of their construction, involving, as it does, nice calculation, founded upon careful observation and experiment.

It may be said, if such advantages are gained by forming bridges in this simple manner, why not have adhered to their principle all along, instead of adopting difficult and intricate plans of construction, which give rise to great additional expense, besides making the subject so much more involved and uncertain? but on the other hand, it must be remarked, that independently of the short duration of timber in comparison of stone, iron, &c., where large spans have to be crossed, it cannot always be obtained of sufficient dimensions, as respects length and depth, and besides, in some localities, a supply of such timbers is not always to be obtained; and even in those where a great quantity was at one period to be found, the very fact of a large consumption leads to a deficiency in the course of time, and trees of a later growth and smaller scantling would necessarily come to be used; and further, in connexion with the application of beams to large spans, it must be borne in mind, that where the distance between the supports becomes greater, the dimensions require to be augmented, and that when the size is increased in an arithmetical proportion the weight is added in a much greater ratio. Under these circumstances, it may easily be conceived, that beam or girder bridges could only be employed within certain circumscribed limits; now, however, that the Britannia Tube has originated the system of building up hollow beams, by which their strength may be made sufficient for the work required of them, without adding so enormously to their weight, we may expect to see wooden-bridges, formed of hollow beams, taking the place of rib and arched timber bridges, and indeed, in some instances superseding both stone and iron, as being calculated for much larger spans than have hitherto been attempted, and capable of being constructed at a comparatively small cost.

But to go back to the history of wooden bridges, we will find that where rivers were broad, and their channels deep, it would be impossible to cross them by single beams of timber. In such cases, a timber framing or scaffolding would be formed in the bed of the river, by driving piles, or a pier might be formed of stones, or other materials. On these, beams of timber would be placed, with one extremity resting on the pier, and the other on the bank of the river, or on an abutment raised at the water's edge, and upon several piers in the water, as the case might be. Where the distance between the supports were too great for the dimensions of the timber forming the roadway, the main beams were propped up by struts projecting from the sides of the piers or piles, which were sometimes made to meet in the centre, or if that was not practicable on account of the distance between the supports, they could each be made to sustain the beam, and a cross-piece on which their ends should abut be placed between them, and fastened to the underside of the beam, these struts, or stays, were then multiplied and disposed in various ways, until at length a rib or arch of timber was formed to support the roadway, while the spandrels were filled up with struts and ties to resist the compression.

The ribs of bridges constructed in this manner were composed of frames, the lower portion of which form segments of circles, frequently made up of several pieces of wood placed immediately one over the other, and joggled together, so arranged, however, that their ends should break joint. To these circular arcs, or polygonal frames, upright pieces were attached either by bolts, mortises, or iron straps, by which the weight of beams supporting the roadway was sustained at intervals, and so disposed as that each part might, as far as possible, conduce to the strength of the whole.

The spandrils, or spaces between the lower rib and the roadway, were differently arranged, according to circumstances; in some there were perpendicular braces, and in others pendant pieces were made to radiate towards the centre of the circle, or polygon, of which the ribs were composed. Again; instead of forming the lower bar of the polygon, &c., by layers of timber bound closely together, it was, in some cases, constructed of two rails placed at some distance from each other, and fastened to radiating pendants, the intermediate spaces being filled up by abutting pieces placed regularly across, so as to keep all the parts of the ribs in their proper places. Besides this, *lattice*-bridges may be mentioned, which consist of two or more frames composed of top and bottom rails, either horizontal or slightly cambered, and the spaces between them filled in with diagonal pieces, crossing one another at an angle of 45°, or some other suitable angle; these pieces are bolted to one another at every crossing, as also to longitudinal walings, and the top and bottom rail; bridges of this description are easily constructed, exceedingly cheap, and have been found to answer extremely well for large spans. In addition to those enumerated, there are a large class of timber-bridges formed on the tension principle, by framing king and queen-posts to the main beam on which the roadway is supported, and bolting to them an upper rail, at the same time filling in the intermediate spaces with ties and truss-bars.

The *Pons Sublicius* was the first bridge ever built across the Tiber. It was at first constructed of timber in the reign of Ancus Martius. It was put together without either bolts or ties, so that it could readily be taken asunder; and was built for the purpose of connecting together the Aventine and Janiculum hills.

The bridge built over the Danube by Trajan is almost one of the oldest timber-bridges of which we have a detailed account. It was supported on twenty stone piers, which were 150 feet high and 6 feet broad; on these were framed timber-arches, each 170 feet span, and formed of three concentric timber-rings bound together by radiating pendants; these, together with the arches, supported the longitudinal beams on which the flooring-joists were placed across the bridge.

It had a simple parapet, formed of a top and bottom rail, supported at intervals by upright posts, with diagonal braces filling in the intermediate spaces. This bridge was unfortunately destroyed by the succeeding emperor, to prevent the possible incursions of the barbarians, by its means, into the Roman territory.

The timber-bridge of Schauffhausen, built over the Rhine, by Ulrick Grubenmann, was remarkable for its ingenious construction; it consisted of two openings, one 172 feet span, and the other about 190. Its abutments and centre-pier were of stone; on these were laid a kind of compound beam, formed of three rails or walings, each of which consisted of two longitudinal beams bolted together, and toothed into each other, so as to be perfectly united; these were supported by an infinity of struts, kept in their places by vertical binding-pieces, all tending to transfer the thrust to the supports of the bridge. It was roofed in for the ostensible purpose of protecting the timber from the bad effects of the weather; but there can be little doubt but that the roof added greatly to its strength; and it is not improbable that its ingenious architect was aware of the important advantages to be derived from its introduction. This bridge, and others designed and executed by the brothers Grubenmann, were in fact *Timber Tubular Bridges.*

The beautiful bridge of Schauffhausen was unfortunately demolished by the French, about the year 1800.

John Grubenmann, assisted by his brother Ulrick, built a splendid bridge of a similar description over the Limmat, having the enormous span of 390 feet. It was formed of two immense circular ribs, one at each side of the roadway, formed of several beams bolted together, and made to fit one into the other, in a similar manner to the Schauffhausen Bridge.

This bridge had also angular struts, longitudinal beams, perpendicular binding-pieces, and abutments of masonry; it was likewise furnished with a roof, which added considerably to the stability of the structure. It was, however, burned down shortly after the destruction of the Schauffhausen Bridge. The bridge at Ceslingen, as also that of Zurich, the one upwards of 200 feet, and the other about 130 feet span, are splendid specimens of this kind of construction, as likewise the bridges of Mellingen and Berne, by Ritter, and those over the Saone by Gauthey.

The timber-bridge of St. Clair, built over the Rhone at Lyons, has seventeen openings, the centre one having a span of 45 feet, and the others diminishing towards each bank. This bridge has a roadway of about 36 feet, which is supported upon piers each formed of 13 piles, arranged in a single row, running parallel with the banks of the river; on the top of these piles a sill was framed, and longitudinal timbers were made to bear over the head of each pile; and upon these longitudinal timbers the flooring was laid.

The bridge of Grenelle, erected over the Seine, near Paris, by M. Mallet, consists of two equal and symmetrical bridges, separated by an intermediate piece of dry ground; each of these is formed of three timber-bays of 82 feet span, supported upon two abutments and two piers of masonry. The width of this bridge is nearly 33 feet. The piers are about 11 feet wide at their foundations, and are diminished to about 9 feet at the springing. The abutments have a half-pier attached to them, on which the timber-work rests. Those at the banks of the river have, besides, two wing-walls. The ground in the centre, measuring 85 feet, the whole bridge, reckoning the entire distance from the abutments on either bank of the Seine, is 632 feet long.

All the foundations were built on piles, upon which a planking was laid. These foundations were formed by means of coffer-dams, easily constructed on account of the shallowness of the river, which, at low water, was not more than 5 feet deep; each bay is composed of seven timber frames, placed about 5 feet apart from each other. The frames consist of segmental ribs, formed of three pieces of bent timber, bolted and bound together by means of iron, which support the roadway by radiating pendants; each of these compound segmental beams is 9 inches square, and of such a length as to take in two of the spaces formed by the pendants. In cutting and placing the frames in position, they were put 5 inches higher than they should have been, in order to allow for sinking, after the flagging was put upon the bridge; and even when opened to the public, the bridge had not settled into its place, so it would seem that 2, or at most, 3 inches, would have been amply sufficient to have allowed for.

Upon the roadway, a layer of bitumen was laid about half an inch thick, in order to prevent the water from injuring the timber of the bridge; however, it must be admitted, that after very heavy rain, the moisture has been found to have percolated through this pavement, either owing to its having been badly laid, or perhaps in consequence of cracks made in this coating by the contraction and expansion of the timber roadway. It might be better, therefore, in future, to place a layer of fine sand between the flooring-boards and the bitumen. Six drain-pipes in each bay convey the water off the surface.

The pavement of the roadway consists of a flagging, 6 inches thick, laid upon sand in the ordinary manner. Each bay is loaded to the extent of about 40 tons.

There is another bridge over the Seine, at Iory, which was put up in the year 1828, and which greatly resembles the bridge of Grenelle in construction.

Besides these, which are given by way of example, there are almost an endless number of wooden-bridges erected throughout the world; among which may be mentioned the bridge at Trenton, in America, of 180 feet span; a bridge over the Tees, 150 feet span; the bridge of Neucetringen, in Bavaria, 102 feet; the bridge across the Necker, 210 feet span; the bridge of Bamberg, with an opening of 206 feet, erected by M. Wiebeking, an engineer, who has constructed an immense number of timber-bridges; the bridge of Feldrich, with a span of 65 feet; the bridge at Zete, built by M. Coffinet, with a span of 125 feet, besides several put up by the celebrated Perronet; and a number of others remarkable for their ingenious construction and variety of form.

Timber bridges are either supported upon piers and abutments of masonry built on the solid foundation of the ground, or on a platform constructed upon piles driven into the earth, or they are supported upon piers formed of one or more rows of piles driven in a line with the road or river passing under the bridge. There are an almost infinite variety of ways in which such props or piers may be made. It is, however, usual to drive the piles about a yard apart from centre to centre, and to bolt capping-pieces or walings to the top of such piles, and either filling up the spaces between with large stones laid dry, or else grouted with mortar; on this, the masonry for the supports should be placed, or a timber-framing, if desired, or else the piles may be carried up to the height of the roadway, being kept in their places by walings and diagonal pieces, bolted on each side of them; these piles should be about a foot square, and when they are driven in salt water, or in tidal rivers, their surfaces, up to high-water mark, should be sheathed with copper, or protected by scupper-nails, from the ravages of the worm. At each end of the piers in the water, in cases where several rows of piles are driven, a sort of cutwater should be formed, in order to ward off heavy bodies, such as floating trees, ice, &c., and prevent them from injuring the superstructure. This is usually done by driving one pile by itself in advance of the rest, or by

forming what is called a *dolphin* at each end of the pier. The piers and abutments should be made in all cases sufficiently strong to resist the thrust of the arch. In cases of small foot-bridges, where even the distance between the supports should be as much as 20 or 30 feet, longitudinal scarfed girders may be laid upon the caps of the piles. Under such circumstances, as we have seen, there is nothing but the weight, or perpendicular pressure, to be provided for; and the same may be said of timber-bridges of greater width, for roads, and even for railways, provided the distance between the piers does not greatly exceed 10 or 15 feet; beyond that opening, however, bridges are usually sustained by struts or tension rods, or the roadway-timbers are trussed so as to exert an oblique pressure upon the supports; indeed, in all instances of the kind, where the bays are formed upon the principle of compression, or tension, the piers must be so formed as to counteract the tendency constantly exerted to force them out of their perpendicular position; this must be done either by making them of sufficient weight and strength so as to overcome, by their inertia, any force that may be exerted against them, or else to counterbalance the efforts of one bay, or arch, acting in one direction, by a similar and similarly-acting arch, or timber-frame, exerting an equal and like force in a contrary direction. The former of these methods is used in the abutments of a bridge, while the latter is invariably adopted with respect to piers.

The roadway of timber-bridges is usually a flooring of boards laid upon the joists; for, in cases where sand and stones are employed, it is found that their weight, together with the humidity they engender, causes the timbers of such bridges speedily to decay. This, however, is far from being a general rule; and many splendid erections of this description are rapidly being destroyed, owing to a want of attention to this important particular. Some have proposed to cover the surface of the roadway with lead, iron, copper, &c., but the increased expense will be a great obstacle to their frequent introduction: we would recommend the wood pavement to be laid as a covering for the roadway of all timber-bridges. The parapet or handrail of these bridges is frequently of wood, or it may be of cast and wrought iron; now, however, that it has been shown how important an addition to the strength of a bridge the sides of a beam are, and that it acts usefully in the direction of its depth, if it has only sufficient breadth to prevent its yielding laterally, we would suggest that in future it should be made available to sustain the bridge, in addition to its present purposes of ornament and protection.

Draw Bridges of timber, made after the manner of a float, to draw up or let down, as occasions serve, before the gate of a town or castle, may be made in several different ways, but the most common are made with plyers twice the length of the gate, and a foot in diameter. The inner space is traversed with a cross, which serves for a counterpoise; and the chains which hang from the extremities of the plyers to lift up or let down the bridge, are of iron or brass. Such bridges are to be seen at Stirling and Edinburgh castles, at the Tower of London, at the castle of Vincennes, and many other regularly-fortified places. In navigable rivers, it is sometimes necessary to form the middle arch of bridges with two movable platforms, to be raised occasionally, in order to let the masts and rigging of ships pass the bridge. There are two piers which support the drawbridge, one of the platforms of which is raised, and the other let down, having a beam for its plyer. To this drawbridge are suspended two movable braces, which, resting on the supports, press against the bracket and thereby strengthen it.

It is one of the first principles of statics, that if two forces are represented, both in amount and direction, by the sides of a parallelogram, then their resultant will be represented by the diagonal of such parallelogram, likewise in direction and intensity. Now, if we reduce the polygonal framing, of which many wooden bridges are formed, to their simplest form, that of two beams abutting against one another, and resting upon two solid supports at their lower ends, we shall find that, inasmuch as the forces will act in the direction of the beams, their weight or gravity tending to keep the ends of the beams against each other by preventing them from rising, will be represented by a vertical line passing through their points of contact, which will be the diagonal of the parallelogram formed by the beams and lines drawn parallel to them at such a point in each as would limit the length of the line to what would fitly represent the force acting in the direction of the beam, and it is evident that the beams being in equilibrio, their horizontal thrusts must be equal and contrary, and consequently will be neutralized by their joint action.

The fact is, in a polygonal framing of any kind, there are three forces exerted at every joint; one in the direction of each beam, and one, a vertical force, acting by gravity, which being the diagonal of the parallelogram constructed upon the beams, is the resultant of the other two, and which, by acting as a counterpoise to the others, keeps the system in equilibrio.

To construct a polygon in any particular instance, we must know the direction and amount of each of the forces, and their points of application; when these are given, we may readily construct the successive sides of a polygonal bridge. It is a well-known fact that gravity always acts vertically; we may, therefore, take a line perpendicular to the horizon, and mark upon it a number of divisions, each one representing the effect of gravity at every successive joint; having, then, found a point at such a distance from it as will represent the horizontal strains which, for a system of forces in equilibrio, are always equal, and connecting that point with the several divisions marked on the vertical line, we shall have a number of right lines which, both in direction and intensity, will respectively represent the force acting at each joint or angle of the framework. Then, by drawing lines parallel to these, placing them one after the other, we shall construct a polygonal frame which will be in equilibrio, bearing in mind that the compressions of any two sides of the polygon are reciprocally as the sines of the angles which they form with the vertical lines, or directly as the secants of their inclination to the horizon.

In order to find the resultant of two forces acting in a given angle, we must add to the sum of the squares of the forces twice their products multiplied into the co-sine of the angle, and extract the square root of the sum, and this will give the required resultant. Again; to ascertain the angle between the resultant and one of the composants, we must divide the product of the sine of the given angle and the lesser force by the product of the co-sine of that angle, and the same force to which the greater force must be added.

It has been maintained, and apparently with a great deal of truth, and several eminent men who have studied the subject deeply have coincided in the opinion, that where an arch is constructed of several key-stones or voussoirs, and remains in equilibrio, its various parts being so adjusted as to cause it to remain without change of position, that a catenary or funicular curve will be found to be wholly included somewhere between its intrados and its extrados. Now, as a wooden bridge, formed on the principle of compression, either by a polygonal frame or with a timber arch, should be made to conform as much to the principle of the arch as possible, so as to make it as strong as can be, with a uniform pressure at

every point by which it may be equally sustained, without throwing an undue strain upon any of the joints or beams, it is well to make the distance between the intrados and extrados as great as can be; hence the advantage of a double arch of timbers, with the intermediate space filled in with judiciously-arranged braces and diagonal pieces, by which the ribs are kept in their proper position without materially increasing the weight.

In the construction of wooden bridges it must be constantly borne in mind that every piece of timber introduced should be placed, as far as can be, so as to bear the strain which will be thrown upon it in the direction of its length; for the more it inclines from the direction of the thrust to which it is opposed, the less resistance it will be capable of exerting, and its useful effect will decline in the ratio of the radius to the sine of the angle of its inclination. In addition to this, the tendency to fracture is much greater by a transverse strain than by a force acting longitudinally by compression through the entire length of the beam.

When it is required to join two or more pieces of timber end to end, so as to make them, together, sufficiently long for any required purpose, the joint made use of in that case is called a scarf. This is made by cutting away a portion of the thickness of the wood in both pieces, so that they may fit into each other: the scarf is then made complete by bolting them well together with iron bolts, or with trenails, and putting iron straps round the joint where necessary. A scarf may be made by cutting away half the wood at the end of each piece, that so they may partially overlie or lap upon each other, or else, in a more advantageous way, by cutting away the wood in a slanting direction, at the same time making indentations or notches in one piece which exactly coincide with similar projections cut near the end of the piece to be joined to it; such scarfs are usually from 18 inches to 3 feet long.

Tenon-and-mortise joints are used for uniting timbers at right angles to one another. The thickness is diminished on both sides at the end of a piece of wood, so as to leave an oblong projection, called a tenon, which is fitted into a space termed a mortise, hollowed out of the piece to which it is to be united, and placed at about a third of the height from the under side; a wooden pin is frequently put through the mortise and tenon so as to prevent them from getting out of their places. A combination of a tenon-and-mortise joint with a scarf is sometimes made for joining timbers longitudinally; and it is found to add greatly to its strength. Scarfs in beams likely to undergo a transverse strain must always be carefully made; they should be very long and well notched, and this tenon-and-mortise joint added, the whole strongly bolted; and it is often a good precaution to put a plate of iron on the under and upper sides of the scarf.

A dove-tail joint is made by forming a tenon increasing in width towards the extremity of the wood, and having a narrow neck near the shoulder; this is fitted to a mortise made in the same shape, on another piece of wood, into which it is admitted laterally; when the wood is hard, this is a good kind of joint, but the ends of the inverted wedges are liable to be broken off if their sides diverge too much, and if they are made in too straight a direction, they are apt to shrink and thus become useless. This joint is, however, very suitable for ties when well made, and it is used in cases where it is thought desirable to secure two horizontal pieces of wood more firmly together, which are joined to one another at an angle. In that case, a piece of wood is made to act as a tie, by being dove-tailed into both the timbers at some distance from the joint.

The ends of struts and braces are usually let into the timbers with which they are connected at the ends by mortise-and-tenon joints; these joints are generally cut at the ends perpendicularly to their direction, and in this way resist the strains which they have to bear more effectually.

A king-post is a principal vertical timber, to which the centres of bays or girders are attached, and by which means, properly speaking, they should be sustained.

Queen-posts are similar to king-posts, but do not occupy so important a position in a piece of carpentry. A number of these may be introduced with great advantage; they should be well framed into the top and bottom timbers, either by halving or by mortise-and-tenon joints; and iron straps should, in most cases, be made use of to make them secure.

The timber, &c., used in the construction of wooden bridges is, according to the position it is made to occupy, obliged to undergo four kinds of forces, which tend to overcome the cohesion exerted between the particles of which it is formed. These are, first, and principally, *transverse pressure*, or a force acting transversely upon a beam, tending thereby to destroy the cohesion and continuity of its fibre, such is the force that the platform of a bridge must be made to resist; such, also, the roof, the joists, the flooring, and many of the levers, of which it is composed. This, however, is a compound force made up of the two succeeding forces. 2nd. A *compressive or crushing* force, which acts longitudinally; this is called generally into play in the framing of the bridge, posts, struts, piles, &c. 3rd. A *tensile* force, in which there is a tendency to pull the particles of the wood from one another, and thus cause a total destruction of its parts by stretching and drawing it to pieces; this force is exerted on king-posts, tie-beams, the under parts of the roadway, and of the joists, walings, &c.; and, lastly, there is a *twisting* force, by which the particles of bolts, rivets, trenails, gudgeons, &c., are strained or wrenched from each other, or are constantly subjected to a force tending so to disunite and destroy them.

In order to prevent these forces from having the effect of injuring the bridge, great care must be taken in the selection of the proper materials; in the manner of disposing them in the bridge, by adopting such an arrangement as will make one force act as a set-off to another by neutralizing its injurious effects, and, above all, by distributing the pressures judiciously, so as never to let any portion of the structure be loaded with more than one-third of the weight which it is calculated to bear without breaking.

In the case of a beam supported at its extremities, it has been found that if it be cut on the upper side, near the middle, to about one-third of its depth, and a piece of hard wood be inserted, in the form of a wedge, so as to give the entire beam a slight camber, that its strength will be increased about a sixth of what it was previously. This plan may be practised with great advantage when the distance between the supports is small, because the rigidity of the material is so much greater in proportion to the weigth to be supported, that the deflexion is not injurious; but when the spans are great, and the props or piers far removed from each other, it becomes necessary to truss the beams to prevent their falling below the horizontal line. This deflexion is as the product of the weight and cube of the length directly, and inversely as the product of the breadth and the cube of the depth. A deflexion of about the fiftieth part of an inch is not very injurious, but, where possible, it should be provided against. It may be well to state here, that the deflexion from a weight uniformly distributed over a bridge is to the deflexion caused by the same weight placed in the centre, as 5 is to 8.

In the event of a beam being loaded up to the point of breaking, it will bend before giving way, and the transverse

strain which would produce this result is in the ratio of the breadth multiplied into the square of the depth, and inversely as the length; and the square of the secant of the angle of deflexion, immediately before giving way altogether, must also form an element of the calculation. When this is ascertained, one-third of this breaking weight must be taken for the maximum load with which it must be weighted.

The inherent qualities of timber and other materials which enable them to resist the force of compression acting in the direction of their length, is directly as the fourth power of their sides in cubic blocks, and as the square of their height inversely. The cohesion of wood, &c., by which it is able to resist the force of tension, or a drawing force, exerted in the direction of its length, varies in the proportion of its cross section. The power of resisting a tensile strain, in different kinds of wood, varies in the ratio of their different specific gravities.

All materials withstand the twisting force of tension when in the form of cylinders, in the ratio of the angle of tension, and the fourth power of the diameter directly, and in the inverse proportion of their length.

The resistance of different woods to pressure, as derived from actual experiment made with blocks of an inch cube, is found to be—for elm, 1,284 lbs.; white deal, 1,928 lbs.; oak, (English) 3,860 lbs.; and pine, (American) 1,606 lbs.

The resistance to tension for bars of an inch square of transverse section, is ascertained to be—for ash, about 11,970 lbs.; beech, 17,371 lbs.; elm, 12,231 lbs.; fir (pitch pine), about 12,917 lbs.; fir (red), 10,829 lbs.; fir (Memel), 10,662 lbs.; fir (Russian), about 9,992 lbs.; fir (American), 870 lbs.; fir (yellow deal), 8,316 lbs.; fir (white deal), 4,204 lbs.; fir (Scotch), 6,569 lbs.; larch, 10,875 lbs.; oak (English), 13,943 lbs.; oak (French), about 14,405 lbs.; oak (Baltic), 11,189 lbs.; oak (American), 10,154 lbs.; oak (Dantzic), 7,558 lbs.; and for willow, about 12,538 lbs.

Oak and fir are principally used in bridge-building, on account of their great durability and hardness, which is a point of very great importance; for the principal objection to wooden bridges in general is, that they are extremely liable to decay; still, their great cheapness, in comparison with bridges constructed of other materials, makes them very suitable in many instances.

WOODEN COLUMN, a column consisting of a trunk, base, and capital, each constructed of wood. The column is glued up in staves, the base in regular sectors, and the capital in blocks used externally. The whole ought to be painted and sanded, in order to produce the effect of a stone column; but if used internally, the painting ought to correspond with that of the apartment in which it is placed.

WORKING DRAWINGS, consist of plans, elevations, and sections of the whole, and all the parts, of an edifice, to as large a scale as may be found convenient; generally in outline, excepting the sectional parts, which are frequently shadowed, or scratched, in order to make them more obvious to the workman, for whose use the drawings are made.

The general plans, elevations, and sections, as they cannot be made to the full size of the object to be executed, should all be figured with numbers of measurement, to show the dimensions of all the parts of the edifice, without obliging the workman to refer to the scale, which is not only very troublesome, but liable to lead to many mistakes detrimental to the work.

The plans, elevations, and sections, of the parts of an edifice, ought to be made to the full size; in which case the figuring of the dimensions becomes unnecessary.

Working drawings may be divided into three classes: distinguished severally as Block Plans, General Drawings, and Detailed Drawings.

Block Plans show no more than the outline of the proposed works or buildings, and their position with reference to surrounding objects; in fact, they point out the site of the buildings, and determine the space to be occupied by them. They are drawn to a small scale, so as to embrace the entire site of the works, and so much of the neighbourhood as may be necessary. They contain every information respecting the present state of the building-ground and its vicinity, and the manner in which it will be affected by the new work; thus, in most instances, it is necessary to show the proposed method of drainage, lighting, water-supply, &c.; and as this will necessarily depend upon the existing state of things, we must mark out the old drains, gas, and water-mains, and the method of connecting them with the new works. It is well also, on such drawings, to give some idea of the comparative levels of the district.

The *General Drawings* show the whole extent of the new works, and the arrangement and distribution of the several parts. They consist of *plans* of the various stories, including those of the foundations, and roofs, and indeed of any part of the building where some peculiar treatment renders explanation necessary; *elevations* of every side of the building, or of so many sides as present a different appearance; and *sections* showing the internal structure and arrangement of the works. On each of these drawings, the dimensions of the whole, and of the various parts, should be carefully figured; the directions in which the measurement are taken, being figured in dotted lines, and the points from and to which they are measured, being clearly defined by an arrow-head, or some such contrivance. So much of the details are shown on these drawings as the scale will allow. Perspective drawings or sketches may be added, to give a more general idea of the undertaking.

The *Detailed Drawings* show such parts of the work as cannot be shown on the general drawings with sufficient clearness and accuracy; and are drawn either of full size, or to such a scale as shall make them clearly intelligible to the workman. Such drawings are required both for the decorative and constructive parts of the building; thus are included the capitals and bases of columns, entablatures, cornices, tracery, or any other enrichment; as also the sections of mouldings, string-courses, &c.; and besides these, the method of framing floors, roofs, &c., the patterns of cast-iron or trussed girders, story-posts, and such like, of everything, in short, of which a particular description is necessary. It saves much trouble, if the detailed drawings are made out on separate sheets for the different trades. These drawings, like the others, should have their dimensions clearly figured upon them, and every drawing should be provided with a scale, from which any further dimensions may be taken by the compasses.

It is usual in drawings, to tint only such parts as are in section; but it will frequently be found desirable to colour also the parts which stand back, and are in elevation; and sometimes also to project the shadows, or shade up such parts, so as to give a general idea of their distance from, and relation to each other, as also of their forms, as whether flat, concave, or convex, &c.

WREATHED COLUMNS, such columns as are twisted in the form of a screw. They are very appropriately called *contorted columns*, as being the offspring of a false taste; for as the primitive use of columns is for supporting a superincumbent weight, whatever diminishes the idea of the stability they ought to afford, is a real blemish; and the very appearance of a twisted column is indicative of weakness.

They were the production of an age when novelty was mistaken for genius, and when meretricious ornament was suffered to usurp the place of real beauty; but since science has resumed her place in the public opinion, they have been laid aside, and are justly considered as blemishes to those buildings in which they appear.

WREN, SIR CHRISTOPHER, the only son of Dr. Christopher Wren, Dean of Windsor, was born at East Knoyle, in Wiltshire, on the 20th of October, 1632. His mother was Mary, daughter and heiress of Mr. Robert Cox, of Fonthill, in the same county. His first education in classic learning was (by reason of his tender health) committed to the care of a domestic tutor, the Rev. William Shepheard, M. A., excepting that for some short time before his admission to the university, he was placed under Dr. Busby, at Westminster School. In the principles of mathematics, upon the early appearance of an uncommon genius, he was initiated by Dr. W. Holder; and he made such rapid progress, that at the age of sixteen he distinguished himself by some important discoveries in astronomy, dialing, statics, and mechanics. While at Oxford, he became acquainted with, and obtained the friendship of, Dr. Scarborough, (afterwards Sir Charles Scarborough,) an eminent physician and mathematician, under whom he performed the part of an assistant, and first introduced geometrical and mechanical sciences to the aid of anatomy. At the age of nineteen, he composed a short algebraic tract relating to the Julian Period, of great use in chronology. In 1650, he was entered Bachelor of Arts at Wadham College, Oxford; where, in 1653, he took the degree of Master of Arts; and in the same year was elected into a fellowship of All-Souls. In 1657 he was chosen Professor of Astronomy in Gresham College, upon the resignation of Dr. Seth Ward; where, in the same year, he read admirable lectures on astronomy; and in 1653 not only solved the problem proposed by the great Pascal to all the English mathematicians, but returned another to those of France, of which they could never furnish any solution. His appointment at Gresham College he resigned in 1660, on being chosen Savilian Professor of Astronomy at Oxford, where, in 1658, he had been created LL.D. as he was shortly afterwards at Cambridge. He had now attained such eminence in architecture, that he was called from Oxford by Charles II. to assist Sir John Denham as surveyor-general of his majesty's works; and in 1663 he was one of the first Fellows of the Royal Society, after the grant of their charter. In 1665 he travelled to France; and it is evident from his letters, that he surveyed every structure with the studious eye of a critic.

After that most dreadful conflagration of London, in the fatal year 1666, had laid the metropolis of England in the dust, Dr. Christopher Wren drew a noble plan for rebuilding it, which he presented to the parliament; and had his scheme been followed, London would have become the most superb metropolis in Europe, or indeed in all the world. It interfered, however, with so many interests in the landed property, that its execution was deemed impracticable. In 1668, on the decease of Sir John Denham, he was appointed surveyor-general and principal architect for rebuilding the whole city, with the cathedral church of St. Paul, and all the parochial churches, in number fifty-one. In the year 1674, the honour of knighthood was conferred upon him; in 1677, he finished the Monument, which has been compared with the celebrated columns of antiquity; in 1680, he was elected president of the Royal Society; and in 1681, he completed his most beautiful structure, the church of St. Stephen, Walbrook; in 1698, he was appointed surveyor-general and commissioner of the works and repairs of the ancient abbey church of St. Peter, Westminster; and in 1710, he finished the magnificent cathedral church of St. Paul.

During the time of his employment in the service of the public and of the crown, by virtue of letters patent, consistent with the pleasure of six crowned heads, under the great seals of King Charles II., King James II., King William and Queen Mary, Queen Anne, and King George I., (besides the ordinary duties of his office in the survey and care of the repairs and new buildings of all the royal palaces,) he began and completed the cathedral church of St. Paul; fifty-one parochial churches; the great column, called The Monument, and other public edifices, in London; the two royal palaces at Hampton Court and Winchester; the royal hospitals of Chelsea and Greenwich; the north front and repairs of Westminster Abbey; the theatre of Oxford; the theatre royal in Drury Lane; the Duke's theatre in Salisbury Court, some time since taken down; the magnificent library of Trinity College, and the elegant chapel of Emmanuel College, Cambridge; with many other fabrics of less note, as well as private seats. All these works form such a body of civil architecture, as will appear rather the production of a whole century than the life and industry of one man, of which no parallel instance can be given.

In an act of parliament of the ninth year of the reign of King William, for completing and adorning the cathedral church of St. Paul, London, a clause was inserted "to suspend a moiety of the surveyor's salary until the said church should be finished; thereby the better to encourage him to finish the same with the utmost diligence and expedition." It was at the time a common notion and misreport, that the surveyor received a large annual salary for that building, and consequently it was his interest to prolong the finishing of the fabric for the continuance of this supposed emolument, which, it would seem, occasioned that clause.

The surveyor's salary for building St. Paul's, from its foundation to its completion, (as appears from public accounts) was not more than two hundred pounds per annum. This, in truth, was his own choice; but what the rest of the commissioners on the commencement of the works judged unreasonably small, considering the extensive charge; the pains and skill in the contrivance, in preparing draughts, models, and instructions for the artificers in their several stations and allotments; in almost daily overseeing and directing in person; in making estimates and contracts; in examining and adjusting all bills and accounts, &c.: nevertheless, he was contented with this small allowance, nor coveted any additional profit, always preferring the public service to any private profit.

Upon the completing of this great fabric, a clause passed in the act of parliament of the ninth year of the reign of Queen Anne, declaring the church finished, to empower the commisioners to pay the surveyor the arrears of the moiety of his salary. His allowance for building all the parochial churches of the city of London was about one hundred pounds per annum, and the same for the repairs of Westminster Abbey.

In the act for building fifty new churches in London and its vicinity, Sir Christopher, though then at a very advanced age, was named one of the commissioners for carrying it into effect. On this occasion he wrote the following letter, for the consideration of his colleagues in office; which, as it contains many points worthy the notice of the architect, is here inserted.

"Since Providence, in great mercy, has protracted my age to the finishing the cathedral church of St. Paul, and the parochial churches of London, in lieu of those demolished by the fire; and being now constituted one of the commis-

sioners for building, pursuant to the late act, fifty more churches in London and Westminster, I shall presume to communicate briefly my sentiments, after long experience; and without farther ceremony, exhibit to better judgment what at present occurs to me in a transient view of this whole affair; not doubting but that the debates of the worthy commissioners may hereafter give me occasion to change or add to these speculations.

"First, I conceive that the churches should be built not where vacant ground may be cheapest purchased in the extremities of the suburbs, but among the thicker inhabitants, for convenience of the better sort, although the site of them should cost more; the better inhabitants contributing most to the future repairs, and the ministers and officers of the churches, and charges of the parish.

"2. I could wish that all burials in churches might be disallowed, which is not only unwholesome, but the pavements can never be kept even, nor pews upright; and if the church-yard be close about the church, this also is inconvenient, because the ground being continually raised by the graves, occasions in time a descent by steps into the church, which renders it damp and the walls green, as appears evidently in all the old churches.

"3. It will be inquired, where then shall be the burials? I answer, in cemeteries, seated in the outskirts of the town; and since it is become the fashion of the age to solemnize funerals by a train of coaches, though the cemeteries should be half a mile or more distant from the church, the charge need be little or no more than usual; the service may be first performed in the church. But for the poor, and such as must be interred at the parish charge, a public hearse of two wheels and one horse may be kept at small expense; the usual bearers to lead the horse, and take out the corpse at the grave. A piece of ground of two acres in the fields will be purchased for much less than two roods among the buildings. This being enclosed with a strong brick wall, and having a walk round, and two cross walks, decently planted with yew trees, the four quarters may serve four parishes, where the dead need not be disturbed at the pleasure of the sexton, or piled four or five upon one another, or the bones thrown out to gain room. In these places beautiful monuments may be erected; but yet the dimensions should be regulated by an architect, and not left to the fancy of every mason, for thus the rich, with large marble tombs, would shoulder out the poor, when a pyramid, a good bust or statue on a proper pedestal, will take up little room in the quarters, and be more proper than figures lying on marble beds. The walls will contain escutcheons and memorials for the dead, and the area good air and walks for the living. It may be considered, farther, that if the cemeteries be thus thrown into the fields, they will bound the excessive growth of the city with a graceful border, which is now encircled with scavengers' dungstalls.

"4. As to the situation of the churches, I should propose, they be brought as forward as possible into the larger and more open streets, not in obscure lanes, nor where coaches will be much obstructed in the passage. Nor are we, I think, too nicely to observe east or west in the position, unless it falls out properly. Such fronts as shall happen to lie most open in view should be adorned with porticoes, both for beauty and convenience; which, together with handsome spires, or lanterns, rising in good proportions above the neighbouring houses, (of which I have given several examples in the city, of different forms,) may be of sufficient ornament to the town, without a great expense for enriching the outward walls of the churches, in which plainness and duration ought principally, if not wholly, to be studied. When a parish is divided, I suppose it may be thought sufficient if the mother-church has a tower large enough for a good ring of bells, and the other churches smaller towers, for two and three bells; because great towers and lofty steeples are sometimes more than half the charge of the church.

"5. I shall mention something of the materials for public fabrics. The earth about London, rightly managed, will yield as good bricks as were the Roman bricks, and will endure in our air beyond any stone our island affords; which, unless the quarries be near the sea, are too dear for general use; the best is Portland or Roch Abbey stone; but these are not without their faults. The next material is the lime. Chalk lime is the constant practice; which, well mixed with good sand, is not amiss, though much worse than hard stone lime. The vaulting of St. Paul's is becoming as hard as stone; it is composed of cockle-shell lime, well beaten with sand: the more labour in the beating, the better and stronger the mortar. I shall say nothing of marble, for this will prove too costly for our purpose, unless for altar-pieces. In windows and doors, Portland-stone may be used, and with good bricks and stone quoins. As to roofs, good oak is certainly the best, because it will bear some negligence. The churchwardens' care may be defective in speedily mending drips; they usually whitewash the church, and set up their names, but neglect to preserve the roof over their heads. It must be allowed, that the roof being more out of sight, is still more unminded. Next to oak is yellow deal, which is a timber of length, and light, and makes excellent work at first, but if neglected, will speedily perish; especially if gutters (which is a general fault in builders) be made to run upon the principal rafters, the ruin may be sudden. Our tiles are ill made, and our slate not good; lead is certainly the best and lightest covering; and being of our own growth and manufacture, and lasting, if properly laid, for many hundred years, is, without question, the most preferable.

"6. The capacity and dimensions of the new churches may be determined by a calculation. They must be large, but must be fitted for auditories. I can hardly think it practicable to make a single room so capacious, with pews and galleries, as to hold above 2000 persons, and all to hear the service, and both to hear distinctly and see the preacher. I endeavoured to effect this in building the parish church of St. James, Westminster, which, I presume, is the most capacious, with these qualifications, that hath yet been built; and yet, at a solemn sime, when the church was much crowded, I could not discern from a gallery that 2,000 were present. In this church I mention, though very broad, and the middle nave arched up, yet there are no walls of a second order, nor lanterns, nor buttresses, but the whole roof rests upon the pillars, as do also the galleries. I think it may be found beautiful and convenient, and as such, the cheapest of any form I could invent.

"7. Concerning the placing of the pulpit, I shall observe, a moderate voice may be heard 50 feet distant before the preacher, and 20 behind the pulpit; and not this, unless the pronunciation be distinct and equal, without losing the voice at the last word of the sentence, which is commonly emphatical, and if obscured spoils the whole sense. A Frenchman is heard farther than an English preacher, because he raises his voice instead of sinking it at his last words. I mention this as an insufferable fault in the pronunciation of some of our otherwise excellent preachers, which schoolmasters might correct in the young, as a vicious pronunciation; and not as the Roman orators spoke, for the principal verb is, in Latin, usually the last word; if that be lost, what becomes of the sentence?

"8. By what I have said, it may be thought reasonable,

that the new church should be at least 60 feet broad, and 90 feet long, besides a chancel at one end, and the belfry and portico at the other. The proportions may be varied; but to build more room than that every person may conveniently hear and see, is to create noise and confusion. A church should not be so filled with pews, but that the poor may have room enough to stand and sit in the alleys, for to them equally is the gospel preached.

"9 I cannot pass over mentioning the difficulties that may be found in obtaining the ground proper for the sites of the churches among the buildings, and the cemeteries in the borders without the town; and therefore I shall recite the method that was taken for purchasing in ground at the north side of St. Paul's cathedral, where, in some places, the houses were but 11 feet distant from the fabric, exposing it to the continual danger of fires. The houses were 17, and contiguous, all in leasehold of the dean, or bishop, or the petty canons, with divers under-tenants. First, we treated with the superior landlords, who, being perpetual bodies, were to be recompensed in kind, with rents of the like value for them and their successors; but the tenants in possession, for a valuable consideration, which, to find what it amounted to, we learned, by diligent inquiry, what the inheritance of houses in that quarter were usually held at. This we found was fifteen years' purchase at the most, and proportionally to this the value of each lease was easily determined in a scheme referring to a map. These rates, which we resolved not to stir from, were offered to each; and to cut off much debate, they were assured that we went by one uniform method, which could not be receded from. The whole at last was cleared, and all concerned were satisfied, and their writings given up. The greatest debate was about their charges for fitting up their new houses to their particular trades; for this we allowed one year's purchase, and gave leave to remove all their wainscot, reserving the materials of the fabric only. This was happily finished without a judicatory, or jury.

"Christopher Wren."

In the year 1685, Sir Christopher Wren was elected and returned a burgess for the borough of Plympton, in the county of Devon, and served in that parliament which began at Westminster on the 29th of May, 1685 in the first year of James II. In the parliament which met at Westminster on the 22nd of June, 1689, he was returned a burgess for the borough of New Windsor, in the county of Berks. In the year 1700, he was returned a burgess for the borough of Weymouth and Melcomb Regis, in the county of Dorset, and served in that parliament which began at Westminster on the 10th of February, in the 12th year of William III.

In 1718, Sir Christopher Wren's patent for the office of surveyor of the royal works was superseded, in the four-score-and-sixth year of his age, and after more than fifty years spent in a continued, active, and laborious service to the crown and public, at which time his merit and labours were not remembered by some. He then betook himself to a country retirement at Hampton Court; where, free from worldly affairs, he passed the greatest part of the five following and last years of his life in contemplation and study, principally of the Holy Scriptures; though he partially turned his thoughts to the discovery of the longitude at sea, and a review of his former tracts on astronomy and mathematics. Time had now greatly enfeebled his limbs, but it had little impaired the vigour of his mind, which continued, with a vivacity rarely found at his age, till within a few days of his dissolution, which happened on the 25th of February, 1723, in the ninety-first year of his age. He was buried in the vault under St. Paul's cathedral, a privilege accorded to him and his family exclusively. A plain stone covers his grave, bearing the appropriate inscription, *Si Monumentum quæris, circumspice:* "If thou seekest my monument, look around thee."

As an architect, his learning was great, and his invention fertile: his discoveries in mathematics and natural philosophy were numerous, and are only eclipsed by his performances in his master-science. He contrived an instrument for measuring the quantity of rain that falls on any space of land for a year: he invented many ways of making astronomical observations more accurately and easily; and was the author of the anatomical experiment of injecting liquors into the veins of animals. He translated into Latin Mr. Oughtred's *Horologiographia Geometrica;* and wrote a *Survey of the Cathedral Church of Salisbury*, and other places. He never printed any of his works, though some have been published by his friends. This excellent artist does not, therefore, derive his glory from his publications, but from the numerous edifices which adorn the British metropolis, and which hourly attract the regard even of the most inattentive.

His private character was extremely amiable, continuing to the last an example of benevolence, free from all moroseness in behaviour or aspect. He left a son, named after himself, who published in 1708, an elaborate treatise on ancient medals, intitled *Numismatum Antiquorum Sylloge*, and died in 1747, aged seventy-two.

X.

XENODOCHIUM, a room in a monastery of religious houses, for the reception and entertainment of strangers.

XYSTOS, or Xystus, (from ξυω, *to make smooth,*) among the ancient Greeks, a portico of unusual length, open or covered, where the athletæ practised wrestling and running. The word is derived from the custom of the athletæ of anointing their bodies with oil before the encounter, to render them smooth, so as to prevent their antagonists from taking hold of them: hence they were called *xystici*, and the place of their exercise *xystos*.

The Romans also had their xystos, which, was a long aisle, or portico, sometimes roofed over, and sometimes open, with trees on each side, forming an agreeable shade to walk under.

Y.

YARD, (from the Saxon, *gerd*), a well-known measure, 3 feet in length; the square yard will, therefore, contain 9 square feet, and the cubic yard 27 solid or cubic feet.

The square yard is used by artificers in measuring their work, and the cubic yard in finding the capacities of cavities dug in the earth. The solid yard is also used in measuring great masses of brick or stone work; of which a few examples, for practice, are here given.

Example 1.—Suppose a room 28 feet 6 inches long, and 14 feet 9 inches wide; how many square yards are contained in the ceiling, or floor?

```
 28  6
 14  9
-------
119  0
 28
 21  4  6
-------
9)420  4  6
-------
 46  6
```

Therefore, the superficial contents are 46 square yards, 6 feet superficial, 4-twelfths of a foot superficial, and 6-twelfths of the twelfth part of a foot superficial, which is the contents of the floor, or ceiling, of the room.

Example 2.—Suppose a pit dug in the earth 58 feet long, 39 feet broad, and 19 feet deep; how many solid yards have been excavated?

```
   58
   39
  ---
  522
 174
 ---
 2262
   19
 ----
 20358
 2262
 ----
27 ) 42978 ( 1591
   27
   --
   159
   135
   ---
    247
    243
    ---
     48
     27
     --
     21
```

So that the contents is 1591 solid yards, and 21 solid feet.

Example 3.—Suppose a mound of earth, whose section is everywhere a given segment of a circle, the breadth of the mound 27 feet, the height 9 feet, and the length 3837 feet; what will be the expense of raising it, at 15d. per yard?

The easiest method of finding the area of tne segment is the following, taken from the article MENSURATION, viz., Multiply the chord and versed sine together, to two-thirds of the product add the cube of the altitude, divided by twice the chord, and the sum will be the area of the section, which, being multiplied by the length of the mound, will give the solidity in feet: see the operation.

```
   27
    9
   --
3 ) 243
   ---
    81
     2
    ---
    162
```

Again,

```
    9
    9
   --
   81
    9
   ---
54 ) 729 ( 13
     54
     --
    189
    162
    ---
     27
```

So that 162 + 13 = 175 feet, the area of the segment.

Then,

```
   3837
    175
   ----
  19185
 26859
 3837
 ----
27 ) 671475 ( 24869
     54
     --
    131
    108
    ---
     234
     216
     ---
      187
      162
      ---
       255
       243
       ---
        12
```

Now 24869 at first is 24869 shillings

at ¼ is ...	6217	3	
2,0)	3108.6	3	
	1554	6	3
and $\frac{12}{27}$ or $\frac{4}{9}$ of a yard is		0	6½
	1554	6	9½

Therefore the whole expense will be £1554 6s. 9½d. *See* Brickwork and Mensuration, where yard-measure is employed.

Yard, an enclosed court or area.

YELLOW, (from the Saxon, *yealewe*,) a colour like that of gold. Yellows are of considerable variety, as yellow ochre, orpiment, gamboge, and many others, too well known to require description.

Z.

ZOP

ZACCO, or Zaccho, (Italian,) the lowest part of a column, or pedestal.

ZAX, an instrument used for cutting slates.

ZETA, or Zeticula, (from the Greek,) a small withdrawing chamber, with pipes conveyed along in the walls to receive from below either the cool air or the heat of warm water; also a stove-room. The term is sometimes extended to signify a parlour, or even a dining-room.

ZIGZAG MOULDING, a moulding common in Norman buildings. *See* Norman Architecture.

ZINC, a bluish-white metal, which tarnishes but slowly when exposed to the air; and on this account is much used in external works, such as roofs, fences, &c.

ZOCCO, or Zocle, a low square member, serving to support a column instead of a pedestal.

A *continued zocle* is that on which an edifice is raised.

ZOPHORUS, (from ζωος, *living*, or ζωον, *an animal*, and φερω, *to bring*,) the frieze, or broad member which separates the cornice and architrave. It was so called by the Greeks, because they adorned it with representations of animals.

The ancients had no fixed proportion of the order for the height of the zophorus. However, in the same order, though the friezes are to be found of different heights in different examples, the variation is not very great.

ZOT

When the zophorus was required to be ornamented, its height was generally enlarged in order to make room for the ornaments. This, however, was not the case with the Grecian Doric, as this extension would have necessarily destroyed the proportion of the triglyphs, and consequently that of the metopes, or spaces between them. The Tuscan order did not admit of any ornaments, and therefore the zophorus, or frieze, was always plain. The Doric, though grand, was extremely elegant, and the metopes were generally ornamented with sculpture, as in the Parthenon and temple of Theseus at Athens. The zophorus of the Ionic and Corinthian orders was not interrupted by any member of the order, as in the Doric, but the ornaments were frequently continued throughout the whole extent, in one or more processions. In the Doric order also, within the pronaos, the triglyphs were always omitted, and in this case the frieze, or zophorus, was adorned, equally with the Ionic and Corinthian, as may be seen within the pronaos of the Parthenon, and that of the temple of Theseus, already referred to. *See* Frieze.

ZOPHORIC COLUMN, any pillar supporting the figure of an animal.

ZOTHECA, a small room or alcove, which might be added to, or separated from, the room to which it adjoined.

ANALYSIS OF CONTENTS.

The CAPITAL letters denote the titles of each article.
The *Italics* " " words referred to under each article.
The Roman " " contents of each article.
The Numeral Letters " " volume.
The Figures " " page.

ÆDI

ABACI, i. 1.
ABACUS, i. 1.
Doric Order, i. 293, 301.
Ionic Order, ii. 18.
Corinthian Order, i. 202.
Tuscan Order, ii. 513.
Roman, or *Composite Order*, ii. 373.
ABBEY, i. 1.
Monastery, ii. 205.
ABBREVIATION, i. 1.
Mensuration of Artificers' Work, ii. 180.
ABREUVOIR, or ABREVOIR, i. 1.
Joint, ii. 85.
ABSTRACT, i. 1.
Mensuration of Artificer's Work, ii. 180.
ABUTMENT, or BUTMENT, i. 1.
Bridges, i. 58.
Wall, ii. 522.
ABUTMENTS in *Carpentry and Joinery*, i. 1.
Joggle, ii. 55.
ACADEMY, i. 1.
ACANTHUS, i. 1.
Orders, ii. 244.
ACCESSES, i. 1.
Passages, ii. 265.
ACCIDENTAL POINT, i. .
Vanishing Point, ii. 515.
ACCOMPANIMENT, i. 1.
ACRE, i. 2.
Measure, ii. 134.
ACROLINTHON, i. 2.
ACROPOLIS, i. 2.
Pelasgian Architecture, ii. 271.
ACROTERIA, i. 2.
ACT, i. 2.
Building Act, i. 67.
ACTUS, i. 2.
Foot, i. 420.
ACUMINATED, i. 2.
ADIT, or ADITUS, i. 2.
ADJACENT, i. 2.
ADYTUM, i. 2.
ADZE, i. 2.
Tools, ii. 494.
ÆDES, i. 2.
ÆDICULA, or SACELLUM, i. 2.

ANG

ÆDICULUS, i. 2.
ÆOLUS, i. 2.
AERIAL PERSPECTIVE, i. 2.
ÆSTUARY, i. 2.
ÆTHERIUS, i. 2.
AGGLUTINATE, i. 2.
AGORA, i. 2.
AGYCI, i. 2.
AISLE, or AILE, i. 2.
Church, i. 151, 152, 158.
Transept, ii. 496.
Wing, ii. 526.
ALABASTER, i. 3.
Gypsum, i. 484.
ALÆ, i. 3.
A-LA-GREC, i. 3.
Frets, i. 434.
ALBARIUM OPUS, i. 3.
ALCOVE, i. 3.
ALESSI, i. 3.
ALHAMBRA, i. 3.
Moorish Architecture, ii. 212.
ALIPTERION, i. 3.
ALMS-HOUSE, i. 3.
AMBO, or AMBON, i. 3.
AMPHIPROSTYLOS, or AMPHIPROSTYLE, i. 3.
Temple, ii. 484.
AMPHITHEATRE, i. 3.
Of its arrangement and form, i. 3.
Description of the Colosseum, Rome, i. 4.
" " Amphitheatre, Verona, i. 4.
" " " Nismes, i. 4.
" of remains of Amphitheatre at Pola, in Istria, i. 4.
AMPHITHURA, i. 5.
ANABATHRUM, i. 5.
ANAGLYPHICE, or ANAGLYPTICE, i. 5.
ANAMORPHOSIS, i. 5.
ANCHOR, i. 5.
ANCONES, i. 6.
ANDREA DE PISA, i. 6.
ANDRON, or ANDRONA, i. 6.
ANGLE, i. 6.
Comparison of Angles, i. 6.
A Right Angle, i. 6.
An Obtuse Angle, i. 6.

An Acute Angle, i. 6.
Measurement of Angles, i. 7.
Arc, i. 7.
External Angle, i. 7.
Internal Angle, i. 7.
Re-entering Angle, i. 7.
Salient Angle, i. 7.
Solid Angle, i. 7.
ANGLE OF A WALL, i. 7.
ANGLE BAR, i. 7.
Raking Mouldings, ii. 359.
ANGLE BRACES, i. 7.
ANGLE BRACKET, i. 7.
Bracketing, i. 42.
ANGLE RAFTER, i. 7.
Hip Roof, i. 496.
ANGLE RIB, i. 7.
Dome, i. 282.
Groin, i. 477.
Hip Roof, i. 496.
ANGLE-STAFFS, or STAFF-BEADS, i. 7.
ANGLE-TILES, i. 7.
Angle-Braces, i. 7.
ANGULAR, i. 7.
ANGULAR CAPITAL, i. 7.
ANGULAR CHIMNEY, i. 7.
Chimney, i. 144.
ANGULAR MODILLIONS, i. 7.
ANNULAR VAULT, i. 7.
ANNULETS, i. 7.
ANNULUS, i. 8.
Mensuration, ii. 172.
ANTÆ, i. 8.
Temple, ii. 484.
ANTECHAMBER, i. 8.
ANTEFIXÆ, i. 8.
ANTEMURAL, i. 8.
ANTEPAGMENTA, i. 8.
ANTERIDES, i. 8.
ANTE-ROOM, i. 8.
ANTES, i. 8.
Antæ, i. 8.
ANTHEMIUS, i. 8.
ANTICS, i. 8.
ANTICUM, i. 8.
ANTIPORTICO, i. 8.
ANTIQUARIUM, i. 8.
ANTIQUE, i. 8.
ANTIQUES, i. 8.
ANTIS, i. 8.
Temple, ii. 484.
Antæ, i. 8.
ANTISTATES, i. 8.
ANTONINE COLUMN, i. 8.
Column, i. 179.
APART, i. 8.
APARTMENT, i. 8.
Windows, ii. 526.
Chimneys, i. 144.
Ceilings, i. 122.
Compartment Ceilings, i. 184.
Vaults, ii. 515.
Stairs, ii. 441.
Doors, i. 288.
Designing, i. 266.
APERTURE, i. 10.
Door, i. 288.
Recess, ii. 360.
Window, ii. 526.
Stone Walls, ii. 464.
Masonry, ii. 119.
Centre, i. 136.
APEX, i. 10.
APODYTERIUM, i. 10.
APOLLODORUS, i. 10.
APOMECOMETRY, i. 10.
APOPHYGE, i. 10.
Column, i. 179.
APOTHECA, i. 10.
APOTHESIS, i. 10.
Apophyge, i. 10.
APPEARANCE, i. 10.
Perspective, ii. 280.
APPLICATE, i. 10.
APPLICATION, i. 10.
APPLICATION *in Geometry*, i. 10.
APRON, i. 11.
Flashing, i. 415.
APRON-PIECE, or PITCHING-PIECE, i. 11.
Stairs, ii. 441.
APRON-LINING, i. 11.
APSIS, i. 11.
Chancel, i. 141.
APIS GRADATA, i. 11.
APTERAL, i. 11.
APYROI, i. 11.
AQUEDUCT, i. 11.
Principal Aqueducts now in existence, i. 11.
ARABESQUE, or MORESQUE, i. 11.
ARABO-TEDESCO, i. 11.
ARÆOPAGUS, i. 11.
Areopagus, i. 17.
ARÆOSTYLE, i. 11.
Intercolumniation, ii. 17.
Colonnade, i. 177.
ARÆOSYSTYLE, i. 11.
Colonnade, i. 177.
ARBOR, i. 11.
ARC, i. 11.
Arc of a Circle, i. 11.
Arcs concentric, i. 11.
Arcs equal, i. 11.
Arcs similar, i. 11.
ARCADE, i. 11.
Thrust of, i. 11.
Proportion and general treatment of in classic styles, i. 12.
Gothic, i. 12.
Arch, i. 12.
ARC-BOUTANTS, i. 12.
Buttress, i. 67.
ARCH, i. 12.
History of, i. 12.
Of the forms, &c., of Arches, i. 13.
Vaulting, ii. 518.
Stone Bridge, ii. 449.
ARCH, TRIUMPHAL, i. 13.
ARCHEION, i. 13.
ARCHITECT, i. 13.
ARCHITECTOGRAPHIA, i. 14.
ARCHITECTURE, i. 14.
Of its Origin and early history, i. 14.
Of its progress, i. 15.
Babylonian Architecture, i. 19.

Byzantine, i. 68.
Celtic, i. 124.
Chinese, i. 145.
Ecclesiastical, i. 312.
Egyptian, i. 351.
English, i. 386.
Etruscan, i. 390.
Gothic, i. 450.
Greek, i. 475.
Hindoo, i. 495.
Italian, ii. 40.
Lombardic, ii. 109.
Mexican, ii. 201.
Moorish, ii. 208.
Norman, ii. 234.
Pelasgian, ii. 270.
Persian, ii. 277.
Pointed, ii. 315.
Roman, ii. 370.
Saxon, ii. 400.
Tudor, ii. 509.
ARCHITRAVE, i. 15.
Tuscan Order, ii. 513.
Doric Order, i. 293.
Ionic Order, ii. 20.
Corinthian Order, i. 202.
Roman Order, ii. 370.
ARCHITRAVE OF A DOOR, i. 16.
ARCHITRAVE, *in Joinery*, i. 16.
Joinery, ii. 65.
ARCHITRAVE CORNICE, i. 16
ARCHITRAVE JAMBS, i. 16.
Architrave of a Door, i. 16.
ARCHIVAULT, i. 16.
Archivolt, i. 16.
ARCHIVE, i. 16.
ARCHIVOLT, i. 16.
ARCS DOUBLEUX, i. 17.
AREA, *in Architecture*, i. 17.
AREA, *in Geometry*, i. 17.
ARENA, i. 17.
ARENATUM, i. 17.
AREOPAGUS, i. 17.
ARONADE, i. 17.
ARRIS, i. 17.
ARRIS FILLET, i. 17.
ARRIS GUTTER, i. 17.
Guttering, i. 483.
ARSENAL, i. 17.
ASAROTUM, i. 17.
ASHLAR, i. 17.
ASHLARING, i. 17.
ASHLERING, i. 17.
ASIMINTHOS, i. 17.
ASPHALTUM, i. 17.
ASSEMBLAGE, i. 17.
ASSEMBLAGE OF ORDERS, i. 17.
ASSERS, i. 17.
ASTRAGAL, i. 17.
Enriched, i. 17.
In Egyptian Buildings, i. 18.
ASULÆ, i. 18.
ASYMPTOTE, i. 18.
ATHENEUM, i. 18.
ATLANTES, ATLANTIDES, or ATLAS, i. 18.
Telamones, ii. 483.
Persians, ii. 280.
ATRIUM, i. 18.
ATTIC, i. 18.
Examples of, i. 18.
ATTIC BASE, i. 18.
ATTIC DOOR, i. 19.
Door, i. 288.
ATTIC ORDER, i. 19.
ATTIC STORY, i. 19.
ATTITUDE, i. 19.
ATTRIBUTES, i. 19.
AUDITORY, i. 19.
AUGER, i. 19.
AULA, i. 19.
AXE, i. 19.
Tools, ii. 494.
AXIS, i. 19.

BABEL, i. 19.
Architecture, i. 14.
BABYLONIAN ARCHITECTURE, i. 19.
Difficulty of affording any correct detailed description, i. 19.
Description of the city of Babylon by Herodotus, i. 19.
Difference between his account, and that of later authors, i. 20.
Description of the city of Babylon by Mr. Rich, i. 20.
Ruins of the Mujelibé, i. 20.
" Jumjuma, i. 20.
Description of large masses of ruins, i. 20.
Description and dimensions of the ruins of the Mujelibé, i. 20.
Description and dimensions of the ruins of the Birs Nemroud, i. 21.
On the identity of the various ruins, i. 21.
On the antiquity of Babylon, i. 22.
Remarks on the amount of credit due to the Mosaic narrative, i. 23.
Observations on the identity of existing ruins, and the city built by Nimrod, i. 23.
Of materials and manner of building, as exhibited in the present ruins, i. 23.
Arch, i. 12.
Of the Birs Nemroud, i. 24.
BACK, i. 24.
BACK OF A CHIMNEY, i. 24.
Chimney, i. 144.
BACK OF A HANDRAIL, i. 24.
Stairs, ii. 441.
Handrailing, i. 487.
BACK OF A HIP-RAFTER, i. 24.
Hip-Roof, i. 496.
BACK LINING OF A SASH FRAME, i. 24.
Sash Frame, ii. 398.
BACK OF A RAFTER, i. 24.
Rafter, ii. 358.
Roof in Carpentry, i. 83.
BACK SHUTTERS OR BACK FLAPS, i. 24.
BACK OF A STONE, i. 24.
BACK OF A WINDOW, i. 24.
BACKING OF A RAFTER OR RIB, i. 24.
Ranging, ii. 360.
Edging, i. 351.
BACKING OF A WALL, i. 24.
BADIGEON, i. 24.
BAGNIO, i. 25.
BAGUETTE, i. 25.

Balbec, i. 25.
Description of architectural remains, **i. 25.**
Balcony, i. 25.
Balustrade, i. 25.
Baldachin, i. 25.
Description of that of St. Peter's, Rome, **i. 25.**
Balection Mouldings, i. 25.
Belection Mouldings, i. 25.
Balks, i. 25.
Balloon, i. 25.
Ball Flower, i. 25.
Balium, i. 25.
Balthei, i. 25.
Baluster, **i. 25.**
Balustrade, i. 25.
Balusters of Ionic Capital, **i. 25.**
Balustrade, i. 25.
Of its position, i. 25.
Of its proportion, i. 26.
Band, i. 26.
Banded Column, i. 26.
Bandelet or Band, i. 26.
Band, i. 26.
Banker, i. 26.
Banqueting Room, i. 26.
Baptistery, i. 26.
Examples of, i. 26.
Font, i. 418.
Bar, i. 27.
Bars for the Shutters of Windows, **i. 27.**
Bars for a boarded Door, **i. 27.**
Bars of a Sash, i. 27.
Angle Bars, i. 7.
Bar Iron, i. 27.
Iron, ii. 22.
Bar Posts, i. 27.
Barbacan or Barbican, *in Fortification*, **i. 27.**
Embrasures, i. 386.
Barbacan, *in Architecture*, **i. 27.**
Barge Boards, i. 27.
Barge Couples, i. 27.
Barge Course, i. 27.
Barn, i. 27.
Its situation, i. 27.
Materials and method of construction, **i. 27.**
Barrel Drain, i. 27.
Drain, i. 304.
Barrow or Tumulus, **i. 27.**
Bas Relief, i. 28.
Basso Relievo, **i. 31.**
Basalt, i. 28.
Base, i. 28.
Base of a Room, **i. 28.**
Basement, i. 28.
Of its proportion, i. 28.
Of its decoration, i. 28.
Of the form of the rustics, **i. 28.**
Basil, i. 28.
Basilica, i. 28.
Description of the Roman, **i. 28.**
Its proportions, i. 28.
Description of that of Julia of Fanum, **i. 28.**
Basilica of St. Peter, Description of, **i. 29.**
" of St. Paul, " **i. 29.**
" of St. Agnes, " **i. 29.**
Of change in their plan and form, **i. 30.**
Description of Basilica of S. Sophia, **i. 30.**
Introduction of Domes, i. 30.
Description of Basilica of St. Peter, **i. 30.**
Modern Basilica, **i. 31.**
In Italy, i. 31.
Description of Basilica at Vicenza, **i. 31.**
Ecclesiastical Architecture, i. 323.
Basket, i. 31.
Basse-Cour, i. 31.
Basso-Relievo, i. 31.
Low-relief, or Basso-Relievo, **i. 31.**
High relief, or Alto Relievo, **i. 31.**
Mean relief, or Mezzo Relievo, **i. 31.**
Terms employed by the Greeks, **i. 31.**
Antiquity of the Egyptian, **i. 31.**
Of the Arabesque, i. 31.
Basso Relievo of the Indians, **i. 32.**
" Persians, **i. 32.**
" Greeks, **i. 32.**
" Romans, **i. 32.**
Bastion or Batoon, **i. 32.**
Torus, ii. 495.
Bat, i. 32.
Bath, **i. 32.**
Batten, i. 32.
Batten Door, **i. 32.**
Door, i. 288.
Batten Floor, **i. 32.**
Boarded Floors, **i. 37.**
Battening, **i. 32.**
Batter, i. 33.
Battle-Embattled, **i. 33.**
Battlements, i. 33.
Baulk, i. 33.
Baulk Roofing, **i. 33.**
Bay, i. 33.
Bay of a Barn, i. 33.
Bay of Joists, i. 33.
Bay Window, i. 33.
Bow Window, i. 41.
Oriel Window, ii. 245.
Bazar or Bazaar, i. 33.
Bead, i. 33.
Bead and Butt Work, **i. 33.**
Bead and Quirk, i. 33.
Bead and Double Quirk, **i. 33.**
Return Bead, ii. 365.
Bead and Flush Work, i. 33.
Bead, Butt, and Square Work, **i. 33.**
Bead, Flush, and Square, **i. 33.**
Beak, i. 33.
Beak-head Moulding, **i. 34.**
Beaking Joint, i. 34.
Beam, i. 34.
Building of Beams, **i. 67.**
Scarfing, ii. 408.
Truss Beams, ii. 509.
Beam Compass, i. 34.
Beam Filling, i. 34.
Bearer, i. 34.
Bearing of a piece of Timber, **i. 34.**
Bearing, i. 34.
Bearing Wall or Partition, **i. 34.**
Beater, i. 34.
Bed Chambers or Bedrooms, i. 34.
Beds of a Stone, i. 34.
Bed of a Slate, i. 34.
Bed Moulding, i. 34.

Beetle, i. 35
Belection Mouldings, i. 35.
Belfry, i. 35.
Bell, i. 35.
Bell Cot, Bell Gable, or Bell Turret, i. 35.
Bell Roof, i. 35.
Belt, i. 35.
Belvedere, or Look-out, i. 35.
Bench, i. 35.
Joinery, ii. 56.
Tools, ii. 494.
Bench Hook, i. 35.
Bend, i. 35.
Bending, i. 35.
Benda, i. 35.
Fascia, i. 413.
Bending, i. 35.
Bernini, Giovanni Lorenzo, i. 35.
Bevel, i. 36.
Billet Mouldings, i. 36.
Binding Joists, i. 36.
Bridging Floors, i. 64.
Binding Rafters, i. 36.
Purlins, ii. 346.
Bird's Mouth, i. 36.
Bit, i. 36.
Shell Bits, i. 36.
Centre " i. 36.
Countersinks, i. 36.
Rimers, i. 36.
Taper Shell Bits, i. 36.
Bitumen, i. 36.
Asphaltum, i. 17.
Blank Door, i. 36.
Blank Window, i. 36.
Blinds, i. 36.
Blocking Course, i. 36.
Blockings, *in Joinery*, i. 37.
Blondel, John Francis, i. 37.
Board, i. 37.
Boarded Floors, i. 37.
Seasoning of Wood, ii. 410.
Preparation of Boards and Joints, i. 37.
Quality of Boards, i. 37.
Various Methods of Laying Floors, i. 37.
Boarding Joists, i. 37.
Boarding Luffer, i. 37.
Luffer Boards, ii. 113.
Lever Boards, ii. 101.
Boarding for Pugging or Deafening, i. 37.
Sound Boarding, ii. 436.
Boarding for Slating, i. 38.
Boarding for Leaden Platforms and Gutters, i. 38.
Boarding for lining Walls, i. 38.
" for outside Walls, i. 38.
Weather Boarding, ii. 522.
Boards Listed, i. 38.
Boards Lever, i. 38.
Boards for the Valleys of a Roof, i. 38.
Valley Boards, ii. 515.
Boaster, or Boasting-tool, i. 38.
Tools, ii. 494.
Boasting, *in Stone-cutting*, i. 38.
Boasting, *in Carving*, i. 38.
Body of a Niche, i. 38.
Niche, ii. 231.
Body of a Room, i. 38.
Body-range of a Groin, i. 38.
Groin, i. 477.
Boffrand, Germain, i. 38.
Bolsters, i. 38.
Balusters of the Ionic Capital, i. 25.
Bolt, i. 38.
Bolts, i. 38.
Bolt of a Lock, i. 38.
Bolts of Iron, i. 38.
Bomon, i. 38.
Bonanno, i. 38.
Bonarotti, Michael Angelo, i. 38.
Bond, *in Building*, i. 39.
Bond, *in Masonry*, i. 39.
Bond-Heart, i. 39.
Bond-Stones, i. 39.
Bond English, i. 39.
Bond Flemish, i. 40.
Bond-Timbers, i. 40.
Bonds, i. 40.
Fir-in-Bond, i. 414.
Boning, i. 40.
Bonom, Joseph, i. 40.
Booth, i. 40.
Borders, i. 40.
Boring, i. 40.
Borromini, Francisco, i. 40.
Boss, i. 41.
Boss, *among Bricklayers*, i. 40.
Bossage, i. 41.
Boulanger, Nicholas Anthony, i. 41.
Boulder Walls, i. 41.
Bound Masonry, i. 41.
Stone Walls, ii. 464.
Boundary Column, i. 41.
Column, i. 183.
Bow, i. 41.
Bow, *amongst Draughtsmen*, i. 41.
Bow Window, i. 41.
Bay Window, i. 33.
Oriel Window, ii. 245.
Box, i. 41.
Box of a Rib-saw, i. 41.
Box for Mitering, i. 41.
Mitre-Box, ii. 204.
Box of a Theatre, i. 41.
Boxings of a Window, i. 41.
Boyle, Richard, i. 42.
Brace, i. 42.
Truss, ii. 508.
Angle Braces, i. 7.
Bracket, i. 42.
Bracket for Shelves, i. 42.
Brackets, i. 42.
Brackets for Stairs, i. 42.
Bracketing, i. 42.
Method of finding angle-brackets, i. 42.
Ranging, ii. 360.
Cove, i. 211.
Dome, i. 275.
Groin, i. 478.
Pendentive Bracketing, ii. 273.
Spandrel " ii. 437.
Spherical " ii. 439.
Spheroidal " ii. 440.
Brads, i. 43.

Bramante, Lazari D'Urbino, i. 43.
Bonarotti, i. 38.
Branches, i. 43.
Brandrith, or Brandrette, i. 44.
Brasses, i. 44.
Breadth, i. 44.
Break, i. 44.
Break-in, i. 44.
Break Joint, i. 44.
Breast of a Chimney, i. 44.
Chimney, i. 144.
Breast of a Window, i. 44.
Breast Wall, i. 44.
Bressummer, or Breast Summer, i. 44.
Timber preferable to Iron, i. 44.
Summer, ii. 480.
Brick, i. 44.
Antiquity of, i. 44.
Size of, i. 45.
Materials for making, i. 45.
Mode of Manufacture, i. 45.
Mode of constructing Clamps for Burning Bricks, i. 46.
Mode of manufacturing Washed Marms or Marls, i. 46.
Mode of burning bricks in Kilns, i. 46.
Of the different varieties of Bricks, i. 46.
Tiles, ii. 489.
Brick Nogging, i. 47.
Brick and Stud, i. 47.
Brick Nogging, i. 47.
Brick Kiln, i. 47.
Bricklayer, i. 47.
Bricklaying Brickwork, i. 47.
Brick, i. 44.
Bricklayer, i. 47.
Mortar, ii. 214.
Tiles, ii. 489.
Cement, i. 128.
Preparation of Ground for foundations, i. 47.
Use of the inverted arch for do., i. 47.
On Ramming foundations, i. 48.
Mode of forming a sound foundation by use of Concrete, i. 48.
Concrete, i. 186.
Preparation of Mortar, i. 48.
Mortar, i. 214.
On Building up of walls, i. 48.
Bond, i. 39.
Different kinds of Bond, i. 48.
Groining or intersection of Arches, i. 49.
Staining Walls, i. 49.
Preservation of unfinished work from effects of rain and frost, i. 49.
Cornices, &c., of Brickwork, i. 49.
Measurement of Brickwork, i. 49.
Materials in a square of tiling, i. 49.
Lime measure, i. 49.
Sand do., i. 49.
To measure trenches for foundations, i. 50.
To measure the footing of a wall, i. 50.
To find the number of rods contained in a piece of Brickwork, i. 50.
To measure the vacuity of a rectangular Window, i. 51.
To calculate the price of a rod of Brickwork, i. 51.
Specimen of Dimension Book, i. 53.
Of Party Walls, i. 55.
Of Flank do., i. 55.
To measure and value Party Walls, Flank Walls, and Partition Walls, with flues, i. 56.
Of single plain tile Creasing, i. 57.
Of double do. do., i. 57.
Of Cut Splays, i. 57.
Of Brick Nogging, i. 57.
Pointing, i. 57.
Flat-joint Pointing, i. 57.
Tuck Pointing, i. 57.
Measurement of Pointing, i. 57.
" Rubbed and Gauged Work, i. 57.
" Circular parts of Drains, i. 57.
" Circular Walls, i. 57.
" Canted Bows, i. 57.
" Brick Cornices, i. 57.
" Garden Walls, i. 57.
" Tiling, i. 57.
" Paving, i. 57.
Mode of Measurement in Cumberland, i. 57.
Do. do., Scotland, i. 57.
Do. do., Ireland, i. 58.
Method of Charging for Materials, i. 58.
Bridge, i. 58.
Abutment, i. 1.
Stone Bridge, ii. 449.
Timber " ii. 491.
Iron " ii. 25.
Suspension " ii. 481.
Origin of Bridges, i. 58.
Arch, i. 12.
Architecture, i. 14.
Suspension Bridges of South America, i. 58.
Suspension Bridge, ii. 481.
Of the Roman Bridges, i. 58.
Pont-du-Garde, near Nismes, i. 59.
Bridge of St. Esprit, i. 59.
Ancient Bridge over the Tagus at Valenza de Alcantara, Spain, i. 59.
Stone Bridge near Brionde, in the Lower Auvergne, i. 59.
Bridge of Avignon, i. 59.
Bridges in Venice, i. 59.
Aqueduct bridge of Alcantara, near Lisbon, i. 59.
Bridge of Neuilly, France, i. 60.
" of Mantes, " i. 60.
" of Allier Moulins, i. 60.
" of St. Maxence, France, i. 60.
" of Orleans, over Loire, i. 60.
Gothic Bridge of Croyland, Lincolnshire, i. 60.
Bridge at Barton-upon-Trent, i. 60.
Gothic Bridge over river Don, near Old Aberdeen, i. 60.
Bridge at York, i. 60.
" Winston, Yorkshire, i. 60.
" Kelso, over the Tweed, i. 60.
" Lancaster, over the Lune, i. 60.
" over the Pease, or Peaths, between Dunbar and Berwick-upon-Tweed, i. 60.
Aqueduct Bridge, Glasgow, i. 61.
Bridge at Perth, i. 61.
Bridge over the Taff at Llantrissent, Glamorganshire, i. 61.
Bridge over Liffey, near Dublin, called Sarah, or Island Bridge, i. 62.
Arran Bridge, Dublin, i. 62.
Essex Bridge, Dublin, i. 62.
Wooden Bridges of Cæsar across the Rhine, i. 62.

Wooden Bridge over the Cismone, i. 62.
" at Wittengen, Switzerland, i. 62.
Wooden Bridge at Schaffhausen, over the Rhine, i. 62.
Schuylkill Bridges at Philadelphia, America, i. 62.
Technical terms used to distinguish the different kinds of Timber Bridges, i. 62.
Pendent or Hanging Bridge, i. 62.
Philosophical " i. 62.
Draw " i. 63.
Swivel " i. 63.
Suspension " i. 63.
Bridges of Boats, i. 63.
Flying or Floating Bridges, i. 63.
Steam Floating Bridge, i. 63.
Portable Bridges, i. 64.
Centre, i. 136.
BRIDGE BOARD, i. 64.
Notch Board, ii. 240.
BRIDGE OVER, i. 64.
BRIDGE STONE, i. 64.
BRIDGED GUTTERS, i. 64.
BRIDGING FLOORS, i. 64.
Naked Flooring, ii. 224.
BRIDGING JOIST, i. 64.
Naked Flooring, ii. 224.
BRIDGINGS, or BRIDGING PIECES, i. 64.
Straining Pieces, ii. 465.
Strutting " ii. 480.
BRING UP, i. 64.
BROACH, i. 64.
BROAD-STONE, i. 64.
Free-Stone, i. 430.
BRONZE, i. 64.
Casting, i. 110.
BROWN, i. 64.
Cologne Earth, i. 176.
Umber, ii. 514.
BRUNELLESCHI, Philip, i. 64.
BUCCULA, i. 65.
BUDGET, i. 65.
BUFFET, i. 65.
BUILDER, i. 65.
BUILDING, i. 65.
Requisite Plans and Estimates, i. 65.
Of Columns and Entablatures, i. 65.
Break, i. 44.
Situation of a building, i. 66.
Plan of do. i. 66.
Apartment, i. 8.
Chimney, i. 144.
Passage, ii. 265.
Roof, ii. 374.
Room, ii. 391.
Staircase, ii. 441.
Of the distribution of Rooms, &c., i. 66.
Of the Form of Buildings, i. 66.
Of Ornaments, i. 66.
Materials for Construction, i. 66.
Chief Writers on Building, i. 67.
Architecture, i. 14.
House, i. 503.
BUILDING, *in Masonry*, i. 67.
Masonry, i. 117.
BUILDING ACT, i. 67.
BUILDING OF BEAMS, i. 67.
Rib, ii. 365.
Scarfing, ii. 408.
BULKER, i. 67.
BULLEN NAILS, i. 67.
BULWARK, i. 67.
Rampart, ii. 359.
Torus, ii. 495.
BUNDLE PILLAR, i. 67.
BUSCHITTO, i. 67.
BUST, or BUSTO, i. 67.
BUT-HINGES, i. 67.
BUTMENT, i. 67.
Abutment, i. 1.
Stone Bridge, ii. 449.
BUTMENT CHEEKS, i. 67.
BUTT-END, i. 67.
BUTT-JOINT, i. 67.
Hand-Railing, i. 487.
BUTTERY, i. 67.
BUTTING-JOINT, i. 67.
BUTTON, i. 67.
BUTTON OF A LOCK, i. 67.
BUTTRESS, i. 67.
Situation of, i. 67.
Of different kinds of Buttresses, i. 67.
Of scientific construction of, i. 67.
Enrichment of Buttresses, i. 68.
BYZANTINE ARCHITECTURE, i. 68.
Its Origin, i. 68.
Its Progress, i. 68.
Introduction of Lombardic style, A. D. 568, i. 68.
Distinguishing characteristics of the Byzantine style, i. 69
Causes for the adoption of this style, i. 70.
Principal Features of edifices erected in this style, from the time of Constantine to the middle of the sixth Century, i. 70.
Do. Do. 2nd period, i. 70.
Do. Do. 3rd period, i. 71.
Description of Cathedral of S. Sophia, Constantinople, i. 71.
Description of S. Vitale, Ravenna, i. 72.
" of S. Ciriaco, Ancona, i. 72.
" of S. Mark's, Venice, i. 72.
" of S. Theodore, Athens, i. 72.

CAABA, i. 73.
Antiquity of, i. 73.
Use of, i. 73.
Description of, i. 73.
CABLE, i. 73.
CABLE FLUTES, i. 73.
CABLING, i. 73.
Flutes, i. 418.
CAGE, i. 73.
CAISSON, i. 73.
Description of those used in building of Westminster Bridge, i. 73.
CAISSON, *in Vaulting*, i. 74.
CALATHUS, i. 74.
CALCAREOUS CEMENTS, i. 74.
Cements, i. 128.
CALCAREOUS EARTH, i. 74.
Limestone, i. 107.
Gypsum, i. 484.
CALENDARIO, Philip, i. 74.
CALIBRE, i. 74.
CALIBRE COMPASSES, or CALLIPERS, i. 74.
CALIDUCTS, i. 74.
CALLIMACHUS, i. 74.

Calotte, i. 74.
Camarosis, i. 74.
Camber, i. 74.
Camber Beams, i. 74.
Instances where required, i. 74.
Camerated, i. 75.
Cames, i. 75.
Camp Ceiling, i. 75.
Campana, i. 75.
Campanile, i. 75.
Canal of the Ionic Volute, i. 75.
Canal, i. 75.
Flute, i. 418.
Canal of the Larmier, i. 75.
Beak, i. 33.
Canardiere, or Guerite, i. 75.
Cancelli, i. 75.
Canopy, i. 75.
Baldachin, i. 25.
Cant, i. 75.
Cant, Moulding, i. 75.
Cantalivers, i. 75.
Canted Column, i. 75.
Canting, i. 75.
Cantharus, i. 75.
Cantharus of a Fountain, i. 75.
Canthers, or Canteril, i. 75.
Canting Stairs, i. 75.
Stairs, ii. 441.
Cantoned Building, i. 75.
Cantoned Columns, i. 75.
Columns, i. 183.
Cap, i. 75.
Cap, *in Joinery*, i. 75.
Capacity, i. 75.
Capital, i. 75.
Of the Doric, i. 76.
" Ionic, i. 76.
" Corinthian, i. 76.
" Tuscan, i. 76.
" Egyptian, i. 76.
" Indian, i. 76.
" Byzantine, i. 76.
" Lombardic, i. 76.
" Gothic, i. 76.
Capital, Angular, i. 76.
Angular Capital, i. 7.
Capital of a Baluster, i. 76.
Capital of a Lantern, i. 76.
Capital of a Triglyph, i. 76.
Capitol,
Celebrated edifices erected on this site, i. 76.
Capreols, i. 77.
Caracol, i. 77.
Caravansera, i. 77.
Carcase, i. 77.
Carcase of Naked Flooring, i. 77.
Carcase Roofing, i. 77.
Carpentry, i. 83.
Roofing, ii. 391.
Truss, ii. 508.
Boarding, i. 37.
Cardinal Scapi, i. 77.
Carina, i. 77.
Carnedde, i. 77.
Carolitic Column, i. 77.
Column, i. 179.
Carpenter, i. 77.
Carpenter's Rule, i. 77.
" Square, i. 78.
" Work, i. 78.
Methods of Measuring various kinds of Carpenter's Work, i. 78.
Tables to find the Price of the common measure of any kind of Workmanship at any time, i. 80.
Carpentry, i. 80.
Of its division into two branches, i. 81.
Descriptive Carpentry, i. 236.
Constructive " i. 193.
Mechanical " ii. 143.
History of Carpentry, i. 81.
Of dividing timbers into scantlings, i. 81.
Of Planing, i. 81.
Tools, ii. 294.
Of the junction and framing of timbers, i. 82.
List of authors on the subject, i. 82.
Godfrey Richards on roofs:— i. 82.
" on flooring, i. 82.
The names of various timbers, i. 83.
Of gable roofs, i. 83.
Of hip roofs, i. 83.
Of flat roofs, i. 83.
To find the length and back of the hip, i. 83.
Of roofs bevel at one end, and square at the other, i. 84.
Of do., bevel at both ends, and of unequal breadth, i. 84.
Mr. Halfpenny:—
To find the angle-bracket of a cove of vaults, and to describe the curves of irregular groins, i. 85.
To find a centre for a semicircular arch in a circular building, i. 86.
To form semicircular and elliptical niches for plastering, i. 86.
Smith's Carpenter's Companion:—
Of lintelings and bond timbers, and their scantlings, i. 87.
Of floors and scantlings for joists, &c., i. 87.
Of trussing girders, i. 88.
Of roofs, their pitch and scantlings, i. 88.
Of timbers of do., i. 88.
Of coved ceilings, i. 89.
Price's "British Carpenter:"—
Scarfing of beams and trussing girders, i. 90.
Roofing and flooring, i. 90.
The method of laying roof in plano, i. 90.
Trusses, i. 92.
Circular and polygonal domes, i. 92.
Centerings for groins, i. 92.
Coverings for coved ceilings and domes, i. 93.
Rampant arches, i. 93.
To find the seat of the angle-ribs of an annular groin, i. 94.
Scantlings of timbers, i. 95.
Of cambering beams, i. 96.
Batty Langley's "Builder's Complete Assistant:"—
Of partitions, i. 96.
Of the strength of timber, i. 96.
Lintels, bond-timbers, and naked-flooring, i. 97.
Strength of Materials, ii. 465.
Scantlings of timbers in floors and roofs, i. 98.
Curvature of hip-rafters for roofs on polygonal plans, i. 99.
Covering of niches and domes, i. 99.
Arches in circular walls, i. 100.

Langley's "Builder's and Workman's Treasury of Designs:"—
Lengthening of beams, i. 101.
To find the angle of a hip, i. 101.
Coverings for niches and domes, i. 101.
Coverings for domes with horizontal joints, i. 102.
Pain's "Builder's Golden Rule:"—
The backing of curve-line hips, i. 102.
The method of coving the angles when there is a circle or oval in the centre of the ceiling, i. 102.
To describe a pentagon on a given side, i. 102.
Coverings of domes of various kinds, i. 103.
Groins, i. 104.
Bevel roofs, i. 104.
Critique upon the above writers, i. 104.
CARPION, i. 106.
CARRIAGE *of a Wooden Stair*, i. 106.
Stair Casing, ii. 441
Handrailing, ii. 487.
CARTELLI, i. 106.
Cartouches, i. 106.
CARTOON, i. 106.
CARTOUCHES, i. 106.
CARVED WORK, i. 107.
Of Mouldings, i. 107.
Of Ovolos, i. 107.
Of Sima Rectas, i. 107.
Of Facias, i. 107.
Of Gothic carved work, i. 107.
CARVEL-BUILT, i. 107.
CARVER, i. 107.
CARVING, i. 107.
Carving Work, i. 107.
CARYATIC, i. 107.
CARYATIC ORDER, i. 107.
Persian Order, ii. 277.
History of, by Vitruvius, i. 107.
Of incorrectness of same, i. 107.
Examples of Caryatides in various styles of architecture, i. 108.
Of Termini, i. 108.
Of Persian Figures, i. 108.
Composition and treatment of Caryatides, i. 108.
CASE, i. 108.
CASE BAYS, i. 108.
CASE *of a Door*, i. 108.
CASE *of a Stair*, i. 108.
CASED, i. 108.
Walls, ii. 522.
CASED SASH FRAMES, i. 108.
Sash Frame, ii.
CASEMATE, i. 108.
CASEMENTS, i. 108.
CASING *of Timber Work*, i. 108.
CAST, i. 109.
Mode of Taking, i. 109.
Introduction of plaster in Architectural Decorations, i. 109.
Substitution of Papier Maché, i. 109.
Of Embossed Leather, i. 109.
Of Gutta Percha, i. 110.
CAST, i. 110.
CAST, ROUGH, i. 110.
Rough Cast, ii. 391.
CASTELLA, or CASTLES, i. 110.
Castle, i. 110.
CASTELLATED HOUSES, i. 110.
CASTING, i. 110.
Cast, i. 109.
CASTING *in Joinery and Carpentry*, i. 110.
CASTING OF BRICK OR STONE WALLS, i. 110.
Rough Cast, ii.
CASTING OF BRONZES, i. 110.
CASTING OF LEAD, i. 110.
Plumbing, ii. 312.
CASTLE, i. 110.
Castella, i. 110.
Origin of, i. 110.
Of early British fortifications, i. 111.
Examples and description of, i. 111.
Inefficiency of, i. 111.
Description of Herefordshire Beacon, i. 111.
" Fortress at Bruff, Staffordshire, i. 111
" Caer Caradoc, Shropshire, i. 111.
" Penmaen Mawr, i. 111.
" Warton Cragg, i. 111.
" Old Oswestry, i. 111.
" Maiden Castle, i. 111.
" Old Sarum, i. 111.
Of Roman military works in this country, i. 111.
At Richborough, i. 111.
" Porchester, i. 112.
" Pevensey, i. 112.
Castle of Colchester, i. 112.
Of the existence of a Castle at Bamborough, i. 112
Of castle-building in time of Alfred the Great, i. 112.
Do. in time of William the 1st. and William Rufus, i. 112.
Description of castles of Anglo-Norman kings, i. 113.
Remains of Berkeley Castle, i. 113.
Castles of time of Edward I., i. 113.
Do. Edward III., i. 114.
Of Castellated Houses, i. 114.
Haddon House, Derbyshire, i. 114.
Quadrangular Houses of Henry VIII.'s time, i. 114.
Decline of Castles, i. 114.
Method of maintaining castles, i. 114.
CASTRA, i. 115.
CASTS, i. 115.
Cast, i. 109.
Casting, i. 110.
CATABASION, i. 115.
CASTABULUM, i. 115.
CATACAUSTIC CURVE, i. 115.
Caustic Curve, i. 122.
CATACOMB, i. 115.
CATADROME, i. 115.
CATAFALCO, i. 115.
CATCH DRAIN, i. 115.
CATENARIA, i. 115.
CATHEDRAL, i. 115.
Comparatively more numerous in the early ages, i.115.
Cathedral erected by Lucius at Winchester, i. 115.
Cathedral erected by St. Augustine, Canterbury, i. 115.
" of St. Paul, London, i. 115.
" St. Andrew, Rochester, i. 115.
" York, i. 115.
Church at Ramsay, i. 116.
Materials, Form, and Disposition of Saxon Cathedrals, i. 116.
Description of Cathedrals existing at the present day, i. 116.
Chronological account of the erection of Cathedral Churches in England, i. 117.

Particular Examples of English cathedrals, i. 117.
Remarkable parts of do., i. 118.
Table of Dates of the principal portions of the English Cathedrals, i. 118.
Admeasurements of the most remarkable parts of the principal cathedral churches of Great Britain, i. 119.
Short description of cathedrals on the Continent, i. 119.
Remarkable parts of foreign cathedrals, i. 120.
Admeasurements of some of the more remarkable Continental cathedrals, i. 120.
Catherine Wheel, i. 120.
Cathetus, i. 120.
Cattle Shed, or Cattle House, i. 120.
Its situation, i. 120.
Directions for construction of, i. 121.
Of the collection of the manure, i. 121.
Of circular houses, i. 121.
Of oblong do., i. 121.
Cow House, i. 211.
Cauking or Cocking, i. 122.
Cocking, i. 174.
Caulicoles, i. 122.
Caulking, i. 122.
Caulking Irons, i. 122.
Causeway, i. 122.
Caustic Curve, i. 122.
Cavædium, i. 122.
Cavazion, Cavasion, or Cavation, i. 122.
Cave, i. 122.
Cavea, i. 122.
Cavetto, i. 122.
Ceiling, i. 122.
Vault, ii. 515.
Various forms of ceiling, i. 122.
Methods of ornamentation, i. 123.
Gothic ceilings, i. 123.
Elizabethan do., i. 123.
Ceiling *in Carpentry*, i. 123.
Bracketing, i. 142.
Ribbing, ii. 365.
Vault, ii. 515.
Ceiling Floor, i. 123.
Ceiling Joists, i. 123.
Cell, i. 123.
Sill, ii. 430.
Cella, i. 123.
Cellar, i. 123.
Cellarage, i. 124.
Celtic, or Druidical Architecture, i. 124.
Of the Celts or Gauls, i. 124.
Of the different kinds of monuments erected by the Celts, i. 124.
Description of Monoliths, i. 124.
Examples at Rudstone, Yorkshire, i. 125.
Uses of round tower, i. 125.
Round Tower, ii. 392.
Description of Cromlechs, i. 125.
Do. of Kist Vaens, i. 125.
Of Kits-Coty House, Kent, i. 125.
Monuments of Palestine, descriptions by Captains Irby and Mangles, i. 125.
Uses of Kist Vaens, i. 125.
Description of Druidical circles, i. 125.
Of Stonehenge and Abury, i. 126.
Examples at Classerniss, Stanton Drew, and Carnac, i. 127.
Description of Logan, or rocking-stones, i. 127.
Example, near Penzance, Cornwall, i. 127.
Description of Tolmen, or hole of stone, i. 128.
Example at Constantine, Cornwall, i. 128.
Description of wring-cheeses, i. 128.
" of one at St. Clare, Cornwall, i. 128.
" of cairns, i. 128.
" of pyramid at New Grange, Drogheda, i. 128.
Description of barrows, or tumuli, i. 128.
Cement, i. 128.
Of natural cements, i. 129.
" calcareous do., i. 129.
" simple limestone and argillo-ferruginous lime, i. 129.
Mortar, its composition and proportions, i. 129.
Grout, i. 130.
Grout, i. 482.
Mortar, for lining of reservoirs, &c., i. 130.
Experiments by Mr. Smeaton and Dr. Higgins, i. 130.
Of the inferiority of modern mortar, i. 130.
Roman method of making mortar, i. 130.
Mortar, ii. 214.
Of water-cements, i. 130.
Discovery of, by the Romans, i. 130.
Of terras, or trass, i. 131.
Substitution of coal-ash for do., i. 131.
Of blue mortar, i. 131.
Ash mortar, i. 131.
Experiments by Mr. Smeaton, i. 131.
Lariot mortar, i. 132.
Mr. Smeaton on do., i. 132.
Recipe for making mortar, where quick concretion is required, i. 132.
Concrete, i. 186.
Of hydraulic limes and ground cements, i. 132.
Mode of preparing artificial hydraulic limes, i. 133.
Maltha, i. 133.
Asphalte, i. 17.
Chunam, i. 134.
Mastic, i. 134.
Roman cement, or compo, i. 134.
Terra cotta, i. 134.
Bailey's composition, i. 134.
Stucco, ii. 480.
Cemetery, i. 134.
Of their situation, i. 135.
Sir C. Wren on extramural interments, i. 135.
Wren, Sir Christopher, ii.
Of foreign cemeteries, i. 135.
Of cemetery at Kensal Green, i. 135.
" Highgate, i. 136.
" Norwood, i. 136.
" Abney Park, i. 136.
South London cemetery, i. 136.
West London do., i. 136.
Cenotaph, i. 136.
Centaur, i. 136.
Centering, i. 136.
Centre, i. 136.
Centering to Trimmers, i. 136.
Centre, or Center, i. 136.
Centre of Gravity, i. 136.
Centre of Pressure, i. 136.
Centre, i. 136.
Centre for groined arch, i. 136.
Ribs and jack-ribs, i. 137.
Stone Bridge, ii. 449.
Of supports for arch-stones, i. 137.

Tredgold on the qualities of a good centre, i. 137.
Directions for construction of centres for bridges, &c., i. 137.
Examples of different modes of construction, i. 138.
Bridge of Orleans, i. 138.
St. Peter's, Rome, i. 138.
Westminster and Blackfriars bridges, i. 138.
Directions for the construction of various kinds of centering, i. 138.
Centre for Chester bridge, i. 139.
Iron Bridge, ii. 25.
Stone do., ii. 449.
Suspension do., ii. 481.
CENTRE, *in Geometry*, i. 139.
CENTRES OF A DOOR, i. 140.
CENTROLINEAD, i. 140.
CENTRY GARTH, i. 140.
CEROFERARIUM, i. 140.
CEROMA, i. 140.
CESTOPHORI, i. 140.
CESSPOOL, i. 140.
Sesspool, ii. 413.
CHAIN TIMBER, i. 140.
CHALCIDICÆ, i. 140.
CHALICE, i. 140.
CHALK, i. 140.
CHAMBER, i. 140.
Of bed-chambers, i. 140.
CHAMBER OF A LOCK, i. 140.
CHAMBER-STORY, i. 140.
CHAMBERS, Sir William, i. 140.
CHAMBRANLE, i. 141.
CHAMFERED RUSTIC, i. 141.
Rustic, ii. 394.
CHAMFERET, i. 141.
CHAMFERING, i. 141.
CHAMP, i. 141.
CHAMPAIN LINE, i. 141.
CHANCEL. i. 141.
Description of, i. 141.
Furniture of, i. 141.
Of the altar, i. 142.
" credence-table, i. 142.
" lettern, i. 142.
" dimensions of chancels, i. 142.
CHANDELIER, i. 142.
CHANDRY, i. 142.
CHANNEL, i. 142.
CHANNEL OF THE LARMIER, i. 142.
Beak, i. 33.
CHANNEL OF THE VOLUTE, i. 142.
Canal of the Ionic Volute, i. 75.
CHANNEL-STONES, i. 142.
CHANTLATE, i. 142.
CHANTRY, or CHAUNTRY, i. 142.
CHANTRIES, i. 143.
CHAPEL, i. 143.
CHAPITER, i. 143.
Capital, i. 75.
Chapiters with mouldings, i. 143.
" with sculptures, i. 143.
CHAPLET, i. 143.
CHAPTER HOUSE, i. 143.
Form and mode of construction, i. 143.
List of chapter houses in England, i. 143.
CHAPTREL, i. 144.
Impost, ii. 2.
CHARGED, i. 144.
CHAR, or CHARE, i. 144.
CHARNEL HOUSE, i. 144.
CHARTOPHYLACIUM, i. 144.
CHASE-MORTISE, or PULLEY MORTISE, i. 144.
CHAUNTRY, i. 144.
Chantry, i. 142.
CHECKERED, or CHECQUERED, i. 144.
Reticulated, ii. 365.
Masonry, ii. 117.
CHEEKS, i. 144.
CHEEKS OF A MORTISE, i. 144.
CHEESE ROOM, i. 144.
CHEQUERS, i. 144.
Masonry, ii. 117.
Reticulated, ii. 365.
CHEST, i. 144.
Caisson, i. 73.
CHEVET, i. 144.
Apsis, i. 11.
CHEVRON WORK, i. 144.
CHIMNEY, i. 144.
Technical terms for different parts of, i. 144.
On the construction of, i. 145.
On the origin of, i. 145.
Examples of different kinds of, i. 145.
CHINESE ARCHITECTURE, i. 145.
Sir William Chambers on, i. 145.
Originality of this style, i. 146.
Pyramidal form of do., i. 146.
Similarity between this and the Greek style, i. 146.
Inapplicability of this style for general purposes in England, i. 146.
Its distinguishing characteristics, i. 146.
Tents the original type of this style, i. 146.
Of Chinese temples, i. 146.
Description of pagoda at Honang, i. 146.
" of three different kinds of ting, i. 147.
" of two little buildings at Canton, i. 147.
Towers or Taas, i. 147.
Description of, i. 148.
Origin and objects of, i. 148.
Celtic Architecture, i. 124.
Description of tower found on the banks of the Taho, i. 148.
Do. Porcelain Tower at Nan King, i. 148.
Several other kinds of buildings used in China, i. 148.
Of a fourth kind of ting, i. 148.
Triumphal arches, i. 148.
Chinese houses, i. 148.
Mode of construction, i. 148.
" of ornamentation, i. 149.
Of their furniture, i. 149.
Description of the different apartments, i. 149.
Materials used for building, i. 150.
Various kinds of columns used by the Chinese, i. 150.
Description and examples of ditto, i. 150.
Description of the Great Wall of China, i. 150.
CHIP, i. 150.
CHISEL, i. 150.
Tools, ii. 494.
CHISELED WORK, i. 150.
CHIT, i. 150.
CHOIR, i. 150.
CHORAGIC MONUMENT, i. 151.
Monument of Lysicrates, ii. 207
CHORD, i. 151.

Christian Architecture, i. 151.
Chronological Column, i. 151.
Column, i. 179.
Church, i. 179.
Various descriptions of Churches, as cathedral, collegiate, &c., i. 151.
Early Christian churches, i. 151.
Vestibule or Narthex, i. 151.
Nave, i. 151.
Aisles, i. 151.
Choir, i. 151.
Ambones, or pulpits, i. 151.
Sanctuary, i. 151.
Altar, i. 151.
Baptistery, i. 151.
Origin of parish churches, i. 151.
Cathedral, i. 115.
Monastery, ii. 105.
Ecclesiastical Architecture, i. 312.
Saxon do. ii. 400.
Of the parts or divisions of a church, i. 152.
Of the position of churches, i. 152.
Of the exterior elevation, i. 152.
Of the tower, i. 153.
Of the internal structure, i. 153.
Of the internal arrangement, i. 153.
Of the internal decoration, i. 154.
Of the materials, i. 155.
Timber church at Greenstead, Essex, i. 155
Of symbolism, i. 156.
Of construction, i. 157.
Of the covering, i. 157.
Of the internal woodwork, i. 157.
Of the flooring, i. 157.
Of the metal work, i. 157.
Of the style, i. 158.
Of the plan, i. 158.
Of the position of the tower, i. 158.
Of apertures, i. 159.
Of the interior, i. 159.
Of the roof, i. 160.
Of pews, i. 160.
Of galleries, i. 160.
Of the principal furniture, i. 160.
Of the lighting and warming, i. 160.
Of the ventilation, i. 160.
Of the restoration of churches, i. 160.
Of the enlargement of do., i. 161.
Church House, i. 161.
Church-Yard, i. 161.
Ciborium, i. 162.
Baldachin, i. 25.
Cilery, i. 162.
Cill, i. 162.
Sill, ii. 430.
Cima, i. 162.
Sima, ii. 430.
Mouldings, ii. 221.
Cima Inversa, i. 162.
Sima Inversa, ii. 430.
Mouldings, ii. 221.
Cima Recta, i. 162.
Sima Recta, ii. 430.
Mouldings, ii. 221.
Cimbra, i. 162.
Cimeliarch, i. 162.
Cincture, or Ceincture, i. 162.
Cinquefoil, i. 162.
Cippus, i. 162.
Circle, i. 162.
Definition of, i. 162.
Measurements of angles, i. 162.
Areas of circles, i. 162.
Proportions of circles, i. 162.
Squaring the circle, i. 162.
Useful properties of the circle, i. 163.
Given the diameter to find the circumference, i. 163.
Given the radius and number of degrees to find the length of an arc, i. 163.
To find the area of a circle, i. 163.
" of a sector, i. 163.
" of a segment, i. 163.
Geometry, i. 440.
Perspective, ii. 280.
Circular Roofs, i. 163.
Circular Winding-Stairs, i. 163.
Circular Work, i. 163.
Circular-Circular, or Cylindro-Cylndric Work, i. 163.
Circumference, i. 164.
Circumferentor, i. 164.
Circumscribe, i. 164.
Circumvallaton, i. 164.
Circumvolution, i. 164.
Volute, ii. 520.
Spiral, ii. 440.
Ionic Order, ii. 18.
Circus, i. 164.
Of the circi of Rome, i. 164.
Description of do., i. 164.
Of games practised therein, i. 165.
Cisoid, or Cissoid, i. 165.
Cistern, i. 165.
Directions for construction of cisterns in cellars, i 165
Do. do. above ground, i. 165.
Do. do. for cattle, i. 166.
Citadel, i. 166.
Of their form, i. 166.
" situation, i. 166.
" fortification, i. 166.
Civic Crown, i. 166.
Civil Architecture, i. 166.
Clair-Obscure, or Chiaro-Obscuro, i. 166.
Clamp, i. 166.
Clamping a board, i. 166.
Clamp, *for brickmaking*, i. 166.
Brick, i. 44.
Clamp Nails, i. 166.
Nails, ii. 224.
Clamping, i. 166.
Clamp, i. 166.
Clasp Nails, i. 166.
Nails, ii. 224.
Classical Architecture, i. 166.
Clathri, i. 166.
Clay, i. 166.
Of unctuous clays, i. 166.
Of meagre " i. 167.
Of calcareous " i. 167.
Claying, i. 167.
Clean, i. 167.
Clear, i. 167.
Clear-Story, i. 167.
Cleaving, i. 167.

Cleeta, i 167.
Palæstra, ii. 253.
Cleopatra's Needles. i. 167.
Clinching, i. 167.
Clinkers, i. 167.
Cloacæ, i. 167.
Sewer, ii. 413.
Cloak-Pins and Rail, i. 167.
Clocharium, or Clochier, i. 167.
Cloghead, i. 167.
Tower, ii. 495.
Cloister, i. 167.
Description of, i. 167.
Lavatory, ii. 94.
Mr. Hope on Continental cloisters, i. 168.
Description of the Campo Santo, Pisa, i. 168.
Cloister attached to St. Stephen's, Westminster, i. 168.
Ecclesiastical Architecture, i. 321.
List of Cloisters of the English cathedrals, i. 168.
Cloister Garth, i. 168.
Close String, i. 168.
Closer, i. 168.
Closet, i. 168.
Water Closet, ii. 522.
Clough, or Clouyse, i. 169.
Clough Arches, or Paddle-Holes, i. 169.
Clout Nails, i. 169.
Nails, ii. 224.
Club Chambers, i. 169.
Plan and elevation of, i. 169.
Warming and ventilation of, i. 169.
Club House, i. 169.
Of early clubs, i. 169.
Of modern do., i. 170.
Of the internal arrangements, i. 170.
Of the United Service, i. 171.
" Athenæum, i. 171.
" Traveller's, i. 171
" Reform, i. 172.
" Carlton, i, 172.
" Oxford and Cambridge University, i. 173.
" Army and Navy, i. 173.
Clump, i. 174.
Clusella, i. 174.
Clustered, i. 174.
Clustered Columns, i. 174.
Coating, i. 174.
Cob-Wall, i. 174.
Cochleare, or Cogla, i. 174.
Cocking, i. 174.
Cockle-Stairs, i. 174.
Stairs, ii. 441.
Cœmeterium, i. 174.
Cemetery, i. 134.
Coffer, i. 174.
Ceilings, i. 122.
Cylindrical Vaults, i. 225.
Coffer, *in Navigation*, i. 174.
Coffer-Dam, i. 174.
In bridge-building, i. 174.
Alberti on coffer-dams, i. 174.
Caisson, i. 73.
Description of coffer-dam at new Houses of Parliament, i. 174.
Coffin, i. 175.
Cogging, i. 175.
Cocking, i. 174.
Coin, or Quoin, i. 175.
Coin Rustic, i. 175.
Rustic, ii. 394.
Colarin, i. 175.
Collarino, i. 175.
Collar, i. 175.
Collar-Beam, i. 175.
Truss, ii. 508.
Collarino, or Colarin, i. 175.
College, i. 175.
St. Augustine's College, Canterbury, i. 175.
Collegiate Church, i. 176.
Cologne Earth, i. 176.
Colonelli, i. 177.
Colonnade, i. 177.
Description of various kinds of coupled, or clustered columns, i. 177.
Coliseum, or Colosseum, i. 177.
Amphitheatre, i. 3.
Colosseum, London, i. 177.
Mr. Hosking on, i. 178.
Of the panorama of London therein exhibited, i. 178.
Colossus, i. 178.
Description of, at Rhodes, i. 178.
Columbaria, i. 179.
Columellæ, i. 179.
Balustrade, i. 25.
Column, i. 179.
Antiquity of, i. 179.
Columns of Egypt, i. 179.
Of reeded columns, i. 179.
Of columns in India, i. 179.
Examples of at temple of Elephanta, and cave of Ellora i. 179.
Examples of columns in Indian pagodas, i. 179.
Of Persian columns, i. 179.
Of Lombardic do., i. 180.
Of Gothic do., i. 180.
Column, *in Classic Architecture*, i. 180.
Parts of, i. 180.
Vitruvius on columns, i. 180.
Attached columns, i. 180.
Proportion of columns, i. 180.
Examples of, i. 180.
Nine methods for the diminution of columns by a curve, i. 181.
Observations on the several methods, i. 181.
Of moulded columns, i. 182.
" fusible do., i. 182.
" transparent do., i. 182.
" scagliola do., i. 182.
" masonic do., i 82.
Stone Column, ii. 463.
Base, i. 28.
Capital, i. 75.
Wooden Column, ii. 531.
Technical terms used to distinguish the different kinds of columns, i. 182.
Columniated Winding Stairs, i. 184.
Stairs, ii. 441.
Coma, i. 184.
Comitium, i. 184.
Commandery, i. 184.
Commissure, i. 184.
Common, i. 184.
Common Centering, i. 184.
Common Joists, i. 184.

Common Pitch, i. 184.
Common Rafters, i. 184.
Communicating Doors, i. 184.
Comparted, i. 184.
Compartition, i. 184.
Compartment, i. 184.
Compartment Ceiling, i. 184.
Compartment Tiles, i. 185.
Compass-headed, i. 185.
Compass Roof, i. 185.
Compass Saw, i. 185.
Saw, ii. 399.
Compass Window, i. 185.
Compasses, i. 185.
Different kinds of, i. 185.
Examples of use of compound proportional compasses, i. 185.
Projection, ii. 328.
Ellipsograph, i. 373.
Pentagraph, ii. 274.
Compassing, i. 185.
Complement, i. 185.
Complement, *in Geometry*, i. 185.
Complement of a Parallelogram, i. 185.
Compluvium, i. 185.
Cavædium, i. 122.
Composite Arch, i. 185.
Composite Base, i. 185.
Composite Capital, i. 185.
Composite Order, i. 185.
Roman Order, ii. 373.
Composition, i. 185.
Compositon, *in Plastering*, i. 186.
Plastering, ii. 307.
Compound Arch, i. 186.
Compound Masonry, i. 186.
Masonry, ii. 117.
Compound Pier, i. 186.
Clustered Column, i. 174.
Compound Proportional Compasses, i. 186.
Compasses, i. 185.
Concamerate, i. 186.
Concatenate, i. 186.
Concave, i. 186.
Concavity of a Curved Line, i. 186.
Concavity of a Solid, i. 186.
Concentric, i. 186.
Concha, i. 186.
Conchoid, i. 186.
Column, i. 181.
Conclave, i. 186.
Concord, Temple of, i. 186.
Description of, i. 186.
Concrete, i. 186.
Composition of, i. 186.
Use of, i. 187.
On the use of as a substitute for stone, i. 187.
" for river walls, break-waters, &c., i. 187.
Example of do. at Woolwich, i. 187.
Captain Denison on the use and manufacture of concrete for the harbour of refuge, Dover bay, i. 187.
Specific gravity of concrete, i. 188.
Of French béton, i. 188.
Concretion, i. 188.
Concurring, or Congruent Figures of Solids, i. 188.
Conduit, i. 188.
Plumbery, ii. 312.
Cone, i. 188.
Properties of, i. 188.
To find the solidity of a cone, i. 189.
To find the curved surface of do., i. 189.
Circle, i. 162.
Conic Section, i. 189.
Ellipsis, or Ellipse, i. 365.
Envelope, i. 387.
Hyperbola, i. 515.
Parabola, ii. 260.
Confessional, or Confessionary, i. 189.
Configuration, i. 189.
Conge, i. 189.
Apophyge, i. 10.
Congeries, i. 189.
Congruity, i. 189.
Conic, i. 189.
Cone, i. 188.
Conic Sections, i. 189.
Treatise on, i. 189.
Ellipse, i. 365.
Parabola, ii. 260.
Hyperbola, i. 515.
Methods of forming sections upon a plane, i. 189.
Concentric ellipses, i. 189.
Parts of an ellipse, i. 189.
Given the abscissa, ordinate, and diameter, to describe an ellipsis or hyperbola, i. 190.
Given the abscissa, ordinate, and a point in the curve, to determine the species and describe the curve, i. 190.
Conical Roof, i. 190.
Conics, i. 190.
Conic Section, i. 189.
Conistra, i. 190.
Conjugate Diameters, i. 190.
Conoid, i. 190.
Definition and kinds of, i. 190.
Generation of, i. 190.
Properties of, i. 190.
Sections of, i. 190.
To find solidity of, i. 190.
Ellipsoid, i. 373.
Paraboloid, ii. 260.
Hyperboloid, i. 515.
Conopeum, i. 191.
Conservatory, i. 191.
Green House, i. 475.
Construction of, i. 191.
Comparative merits of wood and iron, i. 191.
Description of Conservatory in Botanic Garden, Regent's Park, i. 191.
Consistory, i. 192.
Console, i. 192.
Conspiring Powers, i. 192.
Construction, i. 192.
On gravity, i. 192.
Three great principles of construction, i. 192.
Gothic architecture, i. 192.
Construction, *in Geometry*, i. 192.
To find the situation of a point, i. 193.
The intersection of oblique lines, i. 193.
Constructive Carpentry, i. 193.
Descriptive Carpentry, i. 236.
Treatise on, i. 193.

Scarfing, i. 193.
Tabling, i. 194.
Carpentry, i. 90.
Different methods of scarfing, i. 194.
Notching, i. 195.
Framing, i. 196.
Groin centering, i. 197.
Flooring, i. 197.
Partitioning, i. 197
Roofing, i. 197.
Circular roofs and domes, i. 198.
Plaster groins, i. 198.
CONTABULATE, i. 198.
CONTACT, i. 198.
CONTACT, *in Geometry*, i. 198.
CONTENT, i. 198.
CONTEXTURE, i. 198.
CONTIGNATION, i. 198.
CONTIGUITY, i. 198.
CONTIGUOUS ANGLES, i. 198.
Angles, i. 6.
CONTINUED, i. 198.
CONTINUED ATTIC, i. 198.
" PEDESTAL, i. 198.
" PROPORTION, i. 198.
" SCALE, i. 199.
Plinth, ii. 311.
CONTINUOUS BEARINGS, i. 199.
CONTINUOUS IMPOST, i. 199.
CONTORTED, i. 199.
Wreathed, ii. 531.
CONTOUR, i. 199.
CONTRAMURE, i. 199.
CONTRARY FLEXURE, i. 199.
CONTRAST, i. 199.
CONTRAVALLATION, i. 199.
CONVENIENCE, i. 199.
CONVENT, i. 199.
Monastery, ii. 205.
CONVENTUAL CHURCH, i. 199.
CONVERGENT CURVE, i. 199.
Curve, i. 219.
CONVERGENT LINES, i. 199.
CONVEX LINE, i. 199.
CONVEX RECTILINEAR SURFACE, i. 199.
CONVEX SURFACE OF A SOLID, i. 199.
CONVEXITY, i. 199.
CONVOLUTION, i. 199.
COOPER, i. 199.
COOPERY, i. 199.
CO-ORDINATE, i. 199.
CO-ORDINATE PILLARS, i. 199.
COPED TOMB, i. 199.
COPESTONE, i. 199.
COPING, i. 199.
Various kinds of, i. 199.
COPING OVER, i. 200.
CORBEILS, i. 200.
CORBEL, i. 200.
Various kinds of, i. 200.
CORBEL BOLE, i. 200.
Billet Moulding, i. 36.
CORBEL STEPS, i. 200.
CORBEL TABLE, i. 200.
CORBETT, i. 200.
CORBETTIS, i. 200.
CORBS, i. 200.
CORD, i. 200.
Chord, i. 151.
CORDON, i. 200.
CORE, i. 200.
CORICEUM, i. 200.
CORINTHIAN ORDER, i. 200.
Origin of, i. 201.
Description of, i. 201.
" Shaft, i. 201.
" Capital, i. 201.
" Base, i. 202.
" Entablature, i. 202.
Vitruvius on the use of the Doric and Ionic entablatures, i. 202.
Flutings of shaft, i. 203.
Cornice, i. 203.
Vitruvius's proportions for the capital, i. 203.
Proportions of various examples, with table, i. 203.
CORINTHIAN ŒCUS, i. 204.
Œcus, ii. 243.
CORNICE, i. 204.
CORNICE OF AN ORDER, i. 204.
Doric, i. 293.
Ionic, ii. 20.
Corinthian, i. 203.
Tuscan, ii. 514.
Roman, ii. 373.
Origin of, i. 204.
Of modillions and dentils, i. 205.
Of the corona, i. 205.
Corona, i. 205.
Of the various kinds of cornices, i. 205.
CORNUCOPIA, i. 205.
CORONA, i. 205.
CORONA LUCIS, i. 205.
COROSTROTA, i. 205.
CORPS, i. 205.
CORPSE GATE, i. 205.
Lynch Gate, ii. 113.
CORRIDOR, i. 205.
CORSA, i. 205.
Platband, ii. 311.
CORTILE, i. 205.
COSSUTI, i. 205.
COST, i. 205.
COTTAGE, i. 205.
Treatise on, i. 206.
Best modes of constructing, i. 206.
Peculiarities of the English and Scottish, i. 207.
Materials for construction, i. 208.
Specification for a pair of labourers' cottages, i. 208.
COUCH, i. 209.
COUCH, *in Painting*, i. 209.
COULISSE, i. 209.
COUNTER, COMPTER, i. 209.
COUNTER *in Engineering*, i. 209.
COUNTER DRAIN, i. 209.
COUNTER DRAWING, i. 209.
COUNTERFORTS, i. 210.
COUNTER GAUGE, i. 210.
COUNTER LATH, i. 210.
COUNTER LIGHT, i. 210.
COUNTER PARTS, i. 210.
COUNTRY HOUSE, i. 210.
Villa, ii. 519.
House, i. 503.
COUPLE CLOSE, i. 210.

Couple Columns, i. 210.
Couples, i. 210.
Couples Main, i. 210.
Course, i. 210.
Course of the Face of an Arch, i. 210.
Course, *in Slating*, i. 210.
Course of Plinths, i. 210.
Course Barge, i. 210.
Barge Course, i. 27.
Course, Blocking, i. 210.
Blocking Course, i. 36.
Course, Bonding, i. 210.
Course, Heading, i. 210.
Course, Springing, i. 210.
Springing Course, ii. 440.
Course, Stretching, i. 210.
Stretching Course, ii. 480.
Coursed Masonry, i. 210.
Coursing Joint, i. 210.
Court, i. 210.
Cavædium, i. 122.
Cousinet, or Cushion, i. 211.
Cove, i. 211.
Cove Bracketing, i. 211.
Bracketing, i. 42.
Coved and Flat Ceiling, i. 211.
Ceiling, i. 123.
Cover, i. 211.
Cover Way, i. 211.
Covered Way, i. 211.
Covering, i. 211.
Roofing, ii. 391.
Coving, i. 211.
Covings of a Fireplace, i. 211.
Cow House, i. 112.
Cattle Shed, i. 120.
Cow Yard, i. 211.
Crab, i. 211.
Cracking of Buildings, i. 211.
Cracking, *in Plastering*, i. 211.
Cradle, or Coffer, i. 211.
Cradle Vault, i. 211.
Cradling, i. 211.
Cylindric Vault, i. 225.
Cove Bracketing, i. 211.
Dome, i. 275.
Groin, i. 477.
Niche, ii. 231.
Cramp, i. 211.
Crampern, or Cramp Iron, i. 211.
Uses of, i. 211.
Crampoons, i. 212.
Crane House, i. 212.
Creals, i. 212.
Creasing, Tile, i. 212.
Tile Creasing, ii. 489.
Credence, i. 212.
Chancel, i. 142.
Crenelle, i. 212.
Crescent, i. 212.
Cresilla, i. 212.
Cresset, i. 212.
Crest, i. 212.
Crest Tiles, i. 212.
Creux, i. 212.
Crib, i. 212.
Crocket, i. 212.
Croissante Croix, i. 213.
Croket, i. 213.
Crocket, i. 212.
Cronaco Simone, i. 213.
Crooked Line, i. 213.
Crosettes, i. 213.
Crosier, i. 213.
Cross, i. 213.
Cruciform plans in architecture, i. 213.
Boundary, market, and preaching, crosses, i. 213.
Examples of crosses, i. 213.
Cross-banded, i. 213.
Cross-Garnets, i. 213.
Cross-grained Stuff, i. 213.
Cross Multiplication, i. 213.
Treatise on, i. 214.
Examples of, i. 214.
Decimals, i. 228.
Duodecimals, i. 310.
Practice, ii. 323.
Cross Springers, i. 215.
Cross Vaulting, i. 215.
Croude, i. 215.
Crow, i. 214.
Crown, i. 215.
Crown of an Arch, i. 215.
Crown, *in Geometry*, i. 215.
Crown Glass, i. 215.
Glass, i. 447.
Crown Post, i. 215.
Post, ii. 322.
Truss Post, ii. 509.
Crowning, i. 215.
Crucifix, i. 215.
Crypt, i. 215.
Description of crypts at Canterbury cathedral, i. 216.
Crypto-Porticus, i. 216.
Cubature, Cubation, i. 216.
Rule for finding cubation of solids, i. 216.
Solid, ii. 436.
Cube, i. 216.
Properties of, i. 216.
To find superficies of, i. 216.
" solidity of, i. 216.
Cubic Number, i. 216.
Cubicle, i. 216.
Chamber, i. 140.
Cubiculum, i. 216.
Cubit, i. 216.
Cul de Four, or Cu de Four, i. 217.
Cul de Four of a Niche, i. 217.
Culmen, i. 217.
Culvert, i. 217.
Cuneus, i. 217.
Wedge, ii. 522.
Cupboard, i. 217.
Cupola, i. 217.
Curb, i. 217.
Curb for Brick Steps, i. 217.
Curb Plate, i. 217.
" Rafters, i. 217.
" Roof, i. 217.
On construction of, i. 217.
Theory of, i. 218.
The position of several rafters being given in a vertical plane, and movable about their angular points, while the extreme points or ends remain stationary, to find

the proportion of the forces at the angles, so that the rafters may be in equilibrio, i. 217.
Given the vertical angle of a roof, and the proportion of the rafters on each side, to describe the roof to a given width, so that it may be in equilibrio, i. 218.
The angular points at the intersection of the rafters of a roof, held in equilibrio by equal forces at the angles, in directions equidistant from each other, are in the curve of a parabola, i. 218.
The vertical angle and width of the roof being given to construct the roof, so as to have the bottom rafter to the upper in a given ratio, i. 218.
Given the height and width of the roof, as also the number of equal rafters, to describe a roof which shall be in equilibrio by the weight of the rafters, i. 218.
CURB STONES, i. 219.
CURIA, i. 219.
Basilica, i. 28.
CURLING STUFF, i. 219.
CURRENT, i. 219.
CURSOR, i. 219.
Compasses, i. 185.
CURTAIL STEP, i. 219.
Stair, ii. 441.
CURTAIN, i. 219.
CURTICONE, i. 219.
Frustum, i. 435.
Truncated Cone, ii. 508.
CURULE, i. 219.
CURVATURE, i. 219.
CURVE, i. 219.
Its properties, i. 219.
CURVE OF DOUBLE CURVATURE, i. 219.
CURVED SURFACE OF A SOLID, i. 220.
CURVILINEAR, i. 220.
CURVILINEAR ANGLE, i. 220.
Angle, i. 6.
CURVILINEAR ROOF, i. 220.
CURVILINEAR SUPERFICIES OF A SOLID, i. 220.
Curved Surface of a Solid, i. 219.
CURVILINEAR TRIANGLE, i. 220.
CUSHION RAFTER, i. 220.
Principal Brace, i. 323.
CUSP, i. 220.
CUSTOM HOUSE, i. 220.
CUT, i. 220.
CUT BRACKETS, i. 220.
" ROOF, i. 220.
" STANDARDS, i. 220.
" STONE, i. 220.
" WATER, i. 220.
CUTTING PLANE, i. 220.
CUVILLER FRANCOIS, i. 220.
CYCLOGRAPH, i. 220.
Construction and use of, i. 220.
CYCLOID, i. 221.
CYCLOPEAN ARCHITECTURE, i. 221.
Pelasgian Architecture, ii. 279.
CYCLOSTYLAR, i. 221.
CYLINDER, i. 221.
Definition of, i. 221.
Properties of, i. 221
Theory of, i. 221.
To find solidity and surface of, i. 222.
Cross Multiplication, i. 214.
Decimal do. i. 230.
Ellipsis, i. 365.
Given a right cylinder, and three points on its surface, to find the section of the cylinder by a plane passing through the three points, i. 223.
Inclined Plane, ii. 2.
Stereography, ii. 443.
Stereotomy, ii. 444.
To find the section of a segment of a cylinder, given its base, and the position of the cutting plane, i. 223.
CYLINDER SCALINE, i. 224.
CYLINDRICAL, i. 224.
CYLINDRICAL CEILING, i. 224.
CYLINDRICAL COLUMN, i. 225.
Column, i. 179.
CYLINDRICAL VAULTING, i. 225.
" WALLING, i. 225.
" WORK, i. 225.
Joinery, ii. 55.
CYLINDROID, i. 225.
Properties of, i. 225.
To find solidity of, i. 225.
" superficial content, i. 225.
" the envelope, i. 225.
CYMA RECTA, i. 225.
CYMATIUM, i. 225.
CYMATIUM, CIMA, CYMA, or SIMA, i. 225.
Description of, i. 225.
CYMBIA, i. 225.
Fillet, i. 414.
CYPHERING, i. 225.
Chamfering, i. 141.
CYZICENE TRICLINIUM, or HALL, i. 225.
CYZICUM MARMOR, i. 225.

DADO, i. 226.
Description of, i. 226.
Directions for, i. 226.
DAGOUNG, or SHÆDAGON, i. 226.
DAIRY, i. 226.
Situation of, i. 226.
Directions for construction of, i. 226.
Of utensils for a dairy, i. 227.
DAIS, or DEIS, i. 227.
DAM, i. 227.
Embankment, i. 373.
DAMPER, i. 227.
DANCETTE, i. 227.
DARK TENT, i. 227.
DATUM LINE, i. 227.
DAY, or BAY, i. 227,
DEAD SHOAR, i. 227.
Shoaring, ii. 430.
DEAFENING, i. 227.
DEAFENING, *in Plastering*, i. 227.
Pugging, ii. 311.
DEAL, i. 227.
Different kinds of, i. 228.
Mode of cutting, i. 228.
DEBASED, i. 228.
Gothic Architecture, i. 450.
DECAGON, i. 228.
Properties of the, i. 228.
Polygon, ii. 319.
DECAHEDRON, i. 228.
DECAMETRE, i. 228.
DECANICUM, i. 228.
DECASTYLE, or DECASTYLOS, i. 228.

DECEMPEDA, i. 228.
DECIMAL, i. 228.
DECIMAL ARITHMETIC, i. 228.
Treatise on, i. 228.
DECIMAL SCALE, i. 231.
DECIMETRE, i. 231.
DECLINATION, i. 231.
DECLINING DIALS, i. 231.
DECOR, i. 231.
Decorum, i. 232.
DECORATED, i. 231.
Gothic Architecture, i. 450.
DECORATION, i. 231.
DECORATION EXTERNAL, i. 231.
Building Act on, i. 231.
DECORATION OF THE SCENERY OF A THEATRE, i. 232.
DECORUM, or DECOR, i. 232.
Vitruvius on, i. 232.
DEDICATION, i. 232.
DEFINITION, i. 232.
Theory of, i. 232.
Rules for correct definition, i. 233.
DEFLECTION, i. 233.
DEINCLINING DIALS, i. 233.
DELUBRUM, i. 233.
Temple, ii. 483.
DEMI RELIEVO, i. 233.
DEMONSTRATION, i. 233.
Theory of, i. 233.
DEMONSTRATION, GEOMETRICAL, i. 233.
" MECHANICAL, i. 233.
DENDERAH, i. 233.
Description of temple at, i. 234.
DENDROMETER, i. 234.
DENTICLES, i. 234.
Dentils, i. 234.
DENTILS, i. 234.
Proportions of, i. 234.
Examples of, i. 234.
Cornice, i. 204.
DEPARTMENT, i. 235.
DEPOT, i. 235.
Description of, i. 235.
DESCRIBENT, i. 235.
DESCRIPTION *of a building*, i. 235.
Example of, i. 235.
DESCRIPTIVE CARPENTRY, i. 236.
Treatise on, i. 236.
DESCRIPTIVE GEOMETRY, i. 236.
Of its nature, i. 237.
Of the projection of right lines, i. 238.
Of curved surfaces and their generation, i. 239.
The projections of a point and a right line being given, to construct the projections of a line drawn from the given point parallel to the first, i. 240.
To construct the traces of a plane drawn from a point whose projections are given, parallel to another plane whose traces are given, i. 240.
A plane whose two traces are given, and a point whose projections are given, to construct (1) the projections of the right line falling perpendicularly from the point upon the plane; (2) the projection of the point of coincidence of the right line with the plane, i. 241.
The projections of a point and a right line being given, to construct the traces of a plane drawn from the point perpendicularly to the right line, i. 241.
The traces of two planes being given, to construct the projections of the line of their intersection, i. 241.
The traces of two planes being given, to construct the angles formed by them, i. 241.
The projections of two intersecting right lines being given, to construct the angle formed by them, i. 242.
The projections of a right line and the traces of a plane being given, to construct the angle formed by them, i. 242.
The angle formed by two right lines, and the angles formed by such lines with the horizontal planes being given, to construct the horizontal projection of the first of these angles, i. 242.
Of planes tangent to curved surfaces, and of normals, i. 243.
From a supposed point on a cylindric surface, of which the horizontal projection is given, to draw a tangent plane to that surface, i. 244.
Do. on a conic surface, i. 244.
From an imaginary point of a surface revolving upon a vertical axis, and given in horizontal projection, to draw a plane tangent to such surface, i. 244.
The projections of two right lines being given, to construct the projections of their shortest distance, and to find the distance, i. 245.
The necessity for drawing planes tangent to curved surfaces, through points taken from the outside of them, i. 246.
Through a given right line, to draw a tangent plane to the surface of a given sphere, i. 247.
From a given point, to draw a plane tangent to the surfaces of two given spheres, i. 250.
To draw a plane tangent to three spheres of given dimensions and positions, i. 250.
From an arbitrary point, to draw a tangent plane to a given cylindric surface, i. 250.
Do. do. to a given conic surface, i. 251.
From a given line, to draw a tangent plane to a given revolving surface, i. 251.
Of the intersections of curved surfaces, i. 252.
The generating lines of two curved surfaces being known, and all the given lines which fix such generators being determined on the plane of projections, to construct the projections of a curve of double curvature, according to which the two surfaces intersect each other, i. 253.
From a point taken at pleasure upon the intersection of two curved surfaces, to draw a tangent to such intersection, i. 254.
To construct the intersection of a given cylindric surface with a plane of a given position, i. 254.
To construct the intersection of a conic surface of any given base, by a plane given in position, i. 256.
To construct the intersections of two conic surfaces with circular bases, whose axes are parallel to each other, i. 256.
To construct the intersection of two conic surfaces of whatever bases, i. 257.
To construct the intersection of a conic surface of any base with that of a sphere, i. 258.
To construct the development of a conic surface of any base, and to represent upon the surface so developed a section whose two projections are given, i. 259.
To construct the intersection of two cylindric surfaces of any bases, i. 259.
To construct the intersection of two revolving surfaces whose axes are in the same plane, i. 259.

Application of the method of constructing the intersections of curved surfaces to the solution of various questions, i. 261.
To find the centre and radius of a sphere, whose surface passes through four points given arbitrarily in space, i. 261.
To inscribe a sphere in a given triangular pyramid, i. 261.
To construct the projection of a point whose distances from three other points given in space is known, i. 262.
Various practical examples, i. 262.
DESICCATION, i. 265.
DESIGN, i. 265.
Of architectural drawings, i. 266.
Of models, i. 266.
Apartment, i. 8.
Break, i. 44.
Building, i. 65.
House, i. 503.
DESIGNING, i, 266.
DESK, i. 266.
DESTINA, i. 266.
DETACHED COLUMN, i. 266.
Insulated Column, ii. 17.
DETAIL, i. 266.
DETERIORATION, i. 266.
DETERMINATE, i. 267.
DETERMINING LINE, i. 267.
DIACONICON, i. 267.
DIAGONAL, i. 267
Treatise on, i. 267.
DIAGONAL BUTTRESS, i. 267.
" " MOULDING, i. 267.
Zig Zag " , ii. 536.
Dancette " , i. 227.
DIAGONAL PAVING, i. 267.
Pavement, ii. 266.
DIAGONAL RIB, i. 267.
" SCALE, i. 267.
DIAGRAM, i. 267.
DIAL, i. 267.
DIAMETER, i. 267.
Circle, i. 162.
DIAMETER OF A COLUMN, i. 267.
DIAMETER OF A CONIC SECTION, i. 267.
DIAMETER CONJUGATE, i. 267.
Conic Section, i. 267.
DIAMETER OF DIMINUTION, i. 267.
" OF A SPHERE, i. 267.
Sphere, ii. 439.
DIAMETER TRANSVERSE, i. 267.
DIAMETERS CONJUGATE, i. 267.
DIAMOND, i. 267.
DIAMOND FRET, i. 268.
DIAMOND GLASS, i. 268.
Glass,, i. 447.
DIAMOND PAVEMENT, i. 268
Pavement, ii. 266.
DIANA, temple of, i. 268.
Temple, ii. 483.
DIAPER, i. 268.
DIAPERING, i. 268.
Examples of, i. 268.
DIASTYLE, i. 268.
DIATHYRA, i. 268.
DIATONI, i. 268.
DIDORON, i. 268.
DIE, i. 268.
Dye, i. 311.
DIFFERENTIAL, i. 268.
DIGGING, i. 268.
Calculations respecting, i. 268.
Excavation, i. 393.
DIGLYPH, i. 268.
DIKE, or DYKE, i. 268.
DILAPIDATION, i. 268.
Treatise on, i. 268.
DIMENSION, i. 270.
Cross Multplication, i. 214.
Decimals, i. 228.
Duodecimals, i. 310.
Brickwork, i. 47.
DIMENSION BOOK, i. 270.
Brickwork, i. 47.
DIMINISHED BAR, i. 270.
DIMINISHED COLUMN, i. 270.
DIMINISHING RULE, i. 270.
Column, i. 181.
DIMINISHING SCALE, i. 270.
Spiral, ii. 440.
Volute, ii. 520.
DIMINUTION OF COLUMNS, i. 271.
Column, i. 179.
DINING ROOM, i. 271.
House, i. 503.
Room, ii. 391.
DINOCRATES, i. 271.
DIOPHANTINE PROBLEMS, i. 271.
DIOPHANTUS, i. 271.
DIORAMA, i. 271.
Mode of exhibiting, i. 271.
Description of that in Regent's Park, i. 272.
DIPTERON, or DIPTEROS, i. 272.
DIRECT RADIAL, i. 272.
DIRECTING LINE, i. 272.
" PLANE, i. 272.
" POINT, i. 272.
DIRECTOR OF AN ORIGINAL LINE, i. 272.
" OF THE EYE, i. 272.
DIRECTRIX, or DIRIGENT, i. 272.
DIRETTA, i. 272.
Gola, i. 450.
Cima Recta, ii. 430
DISCHARGE, i. 272.
DISCHARGING ARCHES, i. 272.
" STRUTS, i. 272.
DISH OUT, i. 272.
DISHING OUT, i. 272.
DISPLUVINATED CAVÆDIUM, i. 272.
Cavædium, i. 122.
DISPOSITION, i. 272.
DISTANCE OF THE EYE, i. 273.
" POINT, i. 273.
Point of Distance, ii. 315,
DISTANCE OF VANISHING LINE, i. 273.
" INACCESSIBLE, i. 273.
Trigonometry, ii. 496.
DISTEMPER, i. 273.
Directions for mixing colours, i. 273.
DISTRIBUTION, i. 273.
DISTYLE, i. 273.
DITRIGLYPT, i. 273.
DIVAN, i. 273.

Diverging Lines, i. 273.
Dividers, i. 273.
Mathematical Instruments, ii. 130.
Division, Harmonical, i. 273.
Division of an order, i. 273.
Order, ii. 244.
Dock, i. 273.
Description of, i. 273.
Dodecagon, i. 273.
Properties and mensuration of, i. 273
To inscribe in a given circle, i. 274.
Dodecahedron, i. 274.
Properties of, i. 274.
To find solidity of, i. 274.
Dodecastyle, i. 274.
Dog-legged Stairs, i. 274.
To describe the ramps, i. 274.
To find the section of the cap of the newel for the turner, i. 275.
Hand-railing, i. 487.
Staircasing, ii. 441.
Dogs, i. 275.
Endirons, i. 386.
Dog Tooth, i. 275.
Dome, i. 275.
Definition of, i. 275.
Origin and early history of, i. 275.
Description of dome of the Pantheon, i. 275.
" of various Roman domes, i. 276.
" of dome of S. Sophia, Constantinople, i. 276.
" " of S. Mark, Venice, i. 276.
" " of S. Vitale, Ravenna. i. 276.
" " of S. Maria del Foire, Pisa, i. 277.
" " of S. Peter's, Rome, i. 277.
" " of S. Paul, London, i. 278.
" " of Invalides, Paris, i. 278.
" " of the Pantheon, Paris, i. 278.
" of the wooden dome of the Halle du Bled, Paris, i. 278.
" of iron dome of S. Isaac, S. Petersburg, i. 278.
Tables of dimensions of some of the principal domes, i. 279.
Dome requiring no centering, i. 279.
On the equilibrium of domes, i. 280.
To determine the thickness of dome-vaulting when the curve is given, or the curve when the thickness is given, i. 280.
Contours of domes, i. 282.
Given the plan of a square dome, and one of the axal ribs, at right-angles to one of the sides, to find the curve of the angle rib and the covering, i. 282.
Given the plan of an oblong dome, and one of the ribs, to find the hip and the rib parallel to the longitudinal side, also the covering upon the longitudinal and transverse sides, i. 283.
To find the covering of an oblong polygonal dome, i. 283.
To construct the ribs of a spherical dome with eight axal ribs and one purlin in the middle, i. 284.
To find the solidity of a square dome, the axal sections through the middle of the sides being semi-circles, i. 284.
To find the solidity of a dome less than a hemisphere upon a square plan, when its axal sections parallel to the sides are circles, i. 285.
To find the solidity of a truncated square dome, the axal section being that part of a semicircle left by cutting off a segment parallel to the diameter, i. 285.
To find the solidity of a hollow square truncated dome, the shell being of equal thickness, supposing each edge of the base equal to the diameter of the circle of which the section is a part, i. 286.
To find the convex surface of a dome, i. 286.
To find the convex surface of the segment of a dome, independent of the diameter of the great circle, i. 287.
To find the area of the segment of a dome, i. 287.
Given any two parallel chords in a circle and their distance, to find the distance of the greater chord from the centre, i. 287.
Given the chord of a circle and its distance from the centre, to find the radius of the circle, i. 287.
Domestic Architecture, i. 288.
Treatise on, i. 288.
Castles, i. 110.
House, i. 503.
Tudor or Elizabethan Architecture, ii. 509.
Villa, ii. 519.
Roman Architecture, ii. 370.
Domicil, or Domicile, i. 288.
Donjon, or Dongeon, i. 288.
Dooks, i. 288.
Door, i. 288.
Of the aperture for doors, i. 289.
Dimensions of doors, i. 289.
Position of doors, i. 289.
Decorations of doors, i. 289.
Door Baize, i. 289.
Doors Batten, i. 289.
" Framed, i. 289.
Folding Doors, i. 289.
Building act on do., i. 290.
Double doors, i. 290.
Double margin doors, i. 290.
Architrave, i. 15.
Joinery, i. 65.
Doorway, i. 290.
Doorway Plane, i. 290.
Doric Order, i. 290.
Distinguishing characteristics, i. 290.
Of the Doric column and its parts, i. 290.
Of the hypotrachelium, i. 292.
" annulets, i. 292.
" echinus, i. 292.
" abacus, i. 293.
" Doric antæ, i. 293.
" " entablature, i. 293.
" " frieze and triglyph, i. 293.
" " guttæ, i. 293.
" " metopes, i. 293.
" " cornice, i 293.
Tables of proportions, i. 294.
Of intercolumniation, i. 295.
Of the disposition of the triglyphs, i. 295.
Inclination of axis of columns, i. 296.
Description of the Parthenon, i. 296.
" Temple of Theseus, i. 297.
" " Corinth, i. 297.
" Propylea, Athens, i. 298.
" " Eleusis, i. 298.
" Diana Proplea, i. 298.

Description of the Temple of Nemesis, i. 298.
" Remains of two Doric temples, i. 298.
Buildings at Sunium, i. 298.
Description of remains at Thoricus, i. 298.
" of temples of Agrigentum, i. 299.
" " Selinus, i. 299.
" " Segeste, i. 299.
" " Pæstum, Italy, i. 299.
Modern examples of Grecian Doric, i. 300.
Origin of, i. 300.
Similarity of features of Grecian and Egyptian, considered, i. 301.
Grecian, Roman, and Italian Practice, i. 302.
Vitruvius on Doric order, i. 302.
Exemplifications of Grecian Doric, i. 303.
DORMAN, i. 303.
DORMAN TREE, i. 303.
DORMANT, or DORMER, i. 303.
DORMANT TREE, i. 303.
Summer, ii. 480.
DORMITORY, i. 303.
DORON, i. 303.
DOS D'ANE, i. 303.
DOSEL, or DOSER, i. 303.
DOUBLE VAULT, i. 303.
DOUBLE BUILDING, i. 303.
DOUBLE COLUMN, i. 303.
Column, i. 183.
DOUBLE CURVATURE, i. 303.
DOUBLE DOORS, i. 303.
Door, i. 290.
DOUBLE FLOORS, i. 303.
Floor, i. 416.
Naked Flooring, ii. 224.
DOUBLE-HUNG SASHES, i. 303.
DOUBLE-MARGIN DOOR, i. 303.
Door, i. 290.
DOUBLE TORUS, i. 303.
Moulding, ii. 221.
DOUBLE WINDING STAIRS, i. 303
Stairs, ii. 442.
DOUBLING, i. 303.
DOUCINE, or DOUCHINE, i. 303.
DOVE COT, i. 304.
DOVE-TAIL, i. 304.
DOVE-TAILING, i. 304.
DOVE-TAIL MASONRY, i. 304.
Masonry, ii. 117.
DOVE-TAIL MOULDING, i. 304.
DOVE-TAIL NOTCH, i. 304.
DOVE-TAIL SAW, i. 304.
DOWEL, i. 304.
DOWELLING, i. 304.
DRAG, i. 304.
DRAGON PIECE, i. 304.
DRAGON BEAMS, i. 304.
Definition of the term, i. 304.
DRAIN, i. 304.
Drainage, i. 304.
Sewerage, ii. 413.
DRAINAGE, i. 304.
Cloaca, i. 167.
Sewer, ii. 413.
Sewage, ii. 413.
DRAUGHT, i. 304.
Design, i. 265.
DRAUGHT, *in Mechanics*, i. 305.
DRAUGHT, *in Carpentry*, i. 305.
DRAUGHT, *in Masonry*, i. 305.
DRAUGHT COMPASSES, i. 305.
Compass, i. 185.
Instruments, ii. 12.
DRAW BORE, i. 305.
DRAW-BORE PINS, i. 305.
DRAW BRIDGE, i. 305.
Iron Bridge, i. 25.
DRAWING, i. 305.
Treatise on, i. 305.
Shadowing, ii. 424.
DRAWING KNIFE, i. 306.
DRAWING ROOM, i. 306.
Dining Room, i. 271.
Room, ii. 391.
DRAWING SLATE, i. 307.
DRAWINGS, *Working*, i. 307.
Working Drawings, ii. 531.
DRAWN, i. 307.
DREDGING, i. 307.
DRESS, i. 307.
DRESSED, i. 307.
DRESSER, i. 307.
DRESSING ROOM, i. 307.
DRESSINGS, i. 307.
DRIFT, i. 307.
DRIP, i. 307.
Larmier, ii. 93.
Corona, i. 205.
DRIPPING EAVES, i. 307.
DRIPS, i. 307.
DRIPSTONE, i. 307.
DRIVER, *Pile*, i. 307.
Pile Driver, ii. 291.
DROPS, i. 307.
Description of in Doric Architecture, i. 307.
DROVED ASHLAR, i. 308.
Masonry, ii. 117.
DROVED AND BROACHED, i. 308.
DROVED AND STRIPED, i. 308.
DRUIDICAL TEMPLE, i. 308.
Celtic Architecture, i. 124.
DRUM, i. 308.
Dome, i. 275.
DRY ROT, i. 308.
Description of, i. 308.
Causes of, i. 308.
Prevention of, i. 308.
DUBBING, i. 309.
DUN, or BURGH, i. 309.
Description of, i. 309.
Example of at Glenley, i. 309.
DUODECIMALS, i. 310.
Treatise on, i. 310.
Cross Multiplication, i. 214.
DWANGS, i. 311.
DWARF WALLS, i. 311.
DWELLING HOUSE, i. 311.
Building, i. 65.
House, i. 503.
DYE, i. 311.
Dado, i. 226.
DYNAMOMETER, i. 311.
DYPTERON, i. 311.
Dipteron, i. 272.

EAGLE, i. 312.
Reading Desk, ii. 360.
EARS, i. 312.
Crosettes, i. 213.
Ancones, i. 6.
EARTH TABLE, i. 312.
EARTHEN FLOORS, i. 312.
Floors, i. 417.
EATING ROOM, i. 312.
Dining Room, i. 271.
EAVES, i. 312.
EAVES LATH, or EAVES BOARD, i. 312.
EBONY, i. 312.
ECATÆ, i. 312.
ECBATANA, i. 312.
Description of, i. 312.
ECCENTRICITY, i. 312.
ECCLESIASTICAL ARCHITECTURE, i. 312.
Of the churches of the first three centuries, i. 312.
" during apostolic times, i. 313.
Of the hyperoon, or upper room, i. 313.
Observations of Bingham on Dr. Mede, respecting, Christian places of worship of—
" 1st century, i. 313.
" 2nd century, i. 314.
" 3rd century, i. 314.
Objections against the existence of early churches refuted, i. 315.
Further passages on the subject from the patristic writings, i. 315.
Of the nature of the very early churches, and especially of the hyperoon, i. 315.
Extracts from the fathers of the second and third centuries, i. 316.
Destruction of pagan temples by Constantine, i. 317.
Conversion of do. into Christian churches, i. 317.
Do. of basilicas, and Jewish synagogues into do., i. 317.
Do. of British temples into do., i. 317.
Observations in refutation of the conversion of pagan temples into Christian churches, i. 318.
Letter from Constantine to the Bishop of Jerusalem respecting building of Holy Sepulchre, i. 319.
Description of do. from Eusebius, i. 320.
" of church of Paulinus at Tyre, i. 320.
Of other Constantinian churches, and especially of that of S. Constantia, i. 321.
Supposed by some to be a pagan temple, i. 321.
Round Church, ii. 391.
Of the plan of churches, i. 321.
Of their position, i. 321.
Of the vestibule, i. 321.
Of the atrium, and its fountain, i. 321.
Of the pronaos, or narthex, i. 322.
Of the nave, i. 322.
Of the separation of sexes in church, i. 322.
Of the choir, i. 322.
Of the sacrarium, or sanctuary, i. 322.
Of the altar, and its material, i. 322.
Of its ornaments, i. 323.
Of the table of prothesis, i. 323.
Of the baptistery, i. 323.
Of the secretarium, or diaconicum, i. 323.
Of the library, i. 323.
Of other exhedræ, i. 323.
Of the internal decoration of churches, i. 323.
Of basilicas, i. 324.
Of churches built over the tombs of martyrs, i. 324.
To what extent the employment of basilicas affected the form of churches, i. 325.
Of the styles of architecture employed, i. 326.
Byzantine Architecture, i. 68.
Lombardic, " , ii. 109.
Gothic " , i. 450.
Saxon " , ii. 400.
Church, i. 151.
Cathedral, i. 115.
ECHINUS, i. 326.
ECHO, i. 326.
Treatise on, i. 326.
Remarkable instances of, i. 327.
ECHOMETRY, i. 328.
ECPHORA, or ECPHORAN, i. 328.
Projecture, ii. 337.
ECTYPE, i. 328.
EDDYSTONE LIGHTHOUSE, i. 328.
Of previous structures on the site of the present one, i. 328.
Mr. Smeaton's account of Rudyerd's structure, i. 328.
" foundations, i. 328.
" main structure, i. 330.
" lantern, i. 331.
" dimensions, i. 331.
Mr. Smeaton's suggestions for new lighthouse, i. 331.
" as to general form, i. 332.
" method of bonding to the rock: cramping and dovetailing, i. 332.
" first visit to the rock, i. 333.
" choice of materials, i. 333.
" commencement of work-moulds for the stones, i. 333.
" blasting, and key and feather, i. 334.
" preparing rock for foundations, i. 334.
" size and weight of stones, i. 335.
Cement, i. 128.
Mortar, ii. 214.
" progress in foundations, &c., i. 336.
" method of grooving and wedging the stones, i. 338.
" mortar, i. 338.
" method of securing the courses to each other, i. 338.
" marble plugs and joggles for upper courses, i. 339.
" completion of solid part, i. 341.
" of the superstructure, i. 341.
" method of bonding the stones and courses, i. 341.
" joint stones to prevent percolation of water, i. 342.
" cramping, i. 342.
" chain bond, i. 342.
" vertical dimensions, i. 344.
" hoisting and fixing of the lantern, i. 344.
Reference to plates, i. 345.
EDGE, i. 351.
Arris, i. 17.
EDGE OF A TOOL, i. 351.
EDGE TOOLS, i. 351.
EDGING, i. 351.
Backing, i. 24.
Ranging, ii. 360.
EDIFICE, ii. 351.
Building, i. 65.

House, i. 503.
Temple, ii. 483.
EDILE, i. 351.
EFFIGY, i. 351.
EGGS, i. 351.
Echinus, i. 326.
EGYPTIAN ARCHITECTURE, i. 351.
Of the antiquity of the Egyptians, i. 351.
Of the different writers on the subject, i. 351.
Date of remains of temples found by Denon, i. 351.
Character of Egyptian achitecture, i. 351.
Its strength and magnitude, i. 352.
Belzoni's description of temple at Carnac, i. 352.
" portico of Hermopolis, i. 352.
" temple of Tentyra, i. 352.
" observations on the æsthetic character of Egyptian architecture, i. 352.
Of the superiority of Egyptian to Indian art, i. 353.
Of the manual labour employed, in the erection of Egyptian structures, i. 353.
Of the relation between the Egyptian and Gothic styles, i. 353.
Description of temple at Edfou, i. 353.
Of general plans of temples, i. 353.
Of the elevation of temples, i. 354.
Of columns, i. 354.
Of Caryatid figures in the place of columns, i. 355.
Of capitals, i. 355.
Of entablature, i. 356.
Of cornices, i. 356.
Column at Beni-hassan, i. 356.
Column at British Museum, i. 356.
Of bell and vase-shaped capitals, i. 356.
Of square do., i. 356.
Mr. Barry on columns found at Kalaptchie, i. 356.
Columns at Amada, in Nubia, i. 356.
Doric Order, i. 290.
Column, i. 179.
Temple of Jupiter at Carnac, with description, i. 357.
" Luxor, with description, i. 358.
Description of temples at Tentyra, i. 359.
" and palace at Qórneh, by Wilkinson, i. 360.
" tomb of Osimondué, i. 360.
" palace and temple of Remesses II., or, Memnonium, i. 361.
" tomb of Osymandyas, i. 361.
Dimensions of two temples in village of Medinet Abou, i. 362.
Egyptian catacombs, i. 362.
Description of tomb opened by Belzoni, i. 362.
Description of remains in Island of Philoë, i. 363.
Pyramid, ii. 347.
Sphinx, ii. 440.
EGYPTIAN HALL, or BANQUETING-ROOM, i. 364.
Œcus, ii. 243.
EGYPTIAN PYRAMIDS, i. 364.
Pyramid, ii. 347.
EIDOGRAPH, i. 364.
EIDOLON, i. 364.
ELBOWS OF A WINDOW, i. 364.
ELEOTHESION, i. 364.
Palestræ, ii. 253.
ELEVATION, i. 364.
Design, i. 265.
ELIZABETHAN ARCHITECTURE, i. 365.
Tudor Architecture, ii. 512.
ELLIPSIS, i. 365.
Given the two axes to describe the ellipse, i. 365.
Do. do. by trammel, i. 365.
Given an axis and an ordinate to describe the ellipse, i. 365.
Given a diameter and ordinate to describe the curve by a continued motion, i. 365.
To find any number of points in the curve, i. 366.
Given two conjugate diameters, to describe an ellipse through points found in any diameter, i. 366.
Given the axes to describe an ellipse by means of circular arcs passing through twelve or less number of points, i. 367.
To describe an ellipse by instrument, i. 367.
To find the transverse and conjugate axes, i. 368.
Given a diameter and ordinate to find the conjugate diameter, i. 368.
Given two conjugate diameters to find the axis, i. 368.
Given the ellipse and its foci to draw a tangent through a point in the curve, i. 368.
Given two conjugate diameters and the centre, to draw two tangents from a given point without the curve, i. 368.
To describe an ellipse similar to a given one through a given point, having the same centre, and the axes in the same lines, i. 368.
Through the angular points of a given rectangle, to circumscribe an ellipse, which shall have its axes in the same ratio as the sides of the rectangle, i. 368.
To describe an ellipse in a trapezium, i. 369.
To find the area of the segment of an ellipse, i. 369.
To find the periphery of an ellipse, i. 370.
ELLIPSOGRAPH, i. 373.
Ellipsis, i. 365
ELLIPSOID, i. 373.
ELLIPTIC ARCH, i. 373.
ELLIPTIC COMPASSES, i. 373.
Ellipsograph, i. 373.
ELLIPTIC CONOID, i. 373.
Ellipsoid, i. 373.
ELLIPTIC WINDING STAIRS, i. 373.
Stairs, ii. 441.
Winding Stairs, ii. 525.
EMBANKMENT, i. 373.
Different kinds of, i. 373.
Of embankments of stone, i. 373.
Mortar used for construction of, i. 374.
Concrete, i. 187.
Of upright walls and long slopes, i. 374.
Of natural embankments, i. 374.
Reference to plates of different modes of forming embankments, i. 375.
Embankments of brushwood, i. 375.
Proper materials for, i. 375.
Importance of; reclaiming of land, i. 376.
Of proper slope, i. 377.
Diversion of the course of rivers, embankment formed by natural deposit, i. 378.
Reclaiming of land in Norfolk by the process of silting; cost of, &c., i. 378.
The great Bedford level, i. 379.
Embankments in Holland, i. 379.
" in Ireland, i. 379.
Mr. Bazalgette's paper upon do., i. 379.
Mr. Beatson's remarks upon same, i. 380.
Dikes on the banks of the river Po, i. 380.

The Haarlem lake, i. 380.
Embankment of the flooded part of the Amsterdam and Haarlem railway, i. 380.
Embankments of rivers, i. 381.
Value of piling at Portsmouth, i. 381.
Use of jetties on the river Nith, in Dumfriesshire, i. 381.
Obstructions in rivers causing floods, i. 382.
Slope, materials, use of sods, &c., i. 382.
Use of creels, i. 383.
Catch-water drains, i. 383.
Mounds not to be placed too near rivers, i. 383.
Embankments on river Cree, i. 383.
Ingenious method devised by Mr. John Smith, i. 385.
Embankments of canals and railways, i. 385.
Expense of forming banks, i. 386.
EMBATTLED BUILDING, i. 386.
EMBATTLED LINE, i. 386.
EMBATTLED ARONADE, i. 386.
Embattled Line, i. 386.
EMBATTLED BATTLED LINE, i. 386.
EMBLEMATA, i. 386.
EMBOSSING, i. 386.
EMBOSSING, *in Architecture*, i. 386.
EMBRASURE, i. 386.
EMBROIDERY, i. 386.
EMPLECTON, i. 386.
Walls, ii. 522.
ENAMELING, i. 386.
ENCARPUS, i. 386.
ENCAUSTIC, i. 386.
ENCHASING, i. 386.
ENDECAGON, i. 386.
Hendecagon, i. 494.
END IRONS, i. 386.
ENDS OF A STONE, i. 386.
ENGAGED COLUMN, i. 386.
Column, i. 180.
ENGINE PILE, i. 386.
Pile Driver, ii. 291.
ENGLISH ARCHITECTURE, i. 386.
Gothic Architecture, i. 450.
Domestic Architecture, i. 288.
ENGLISH BOND, i. 386.
ENGLISH OAK, i. 386.
ENNEAGON, i. 386.
ENSEMBLE, i. 386.
ENTABLATURE, i. 386.
Description of, i. 386.
Division of, i. 386.
Doric Architecture, i. 290.
Height of, i. 386.
Rule to find the proportions of the different parts of, i. 386.
ENTABLATURE AND ENTABLEMENT, i. 387.
ENTAIL, i. 387.
ENTASIS, i, 387.
Column, i. 180.
ENTER, i. 387,
ENTERSOLE, i. 387.
Mezzanine, ii. 203.
ENTRY, i. 387.
ENVELOPE, i. 387.
Soffit, ii. 484.
To develope that portion of the curved surface of a cylindroid which is contained between two parallel planes, and another plane passing through the axis at right-angles with the parallel planes, i. 387.
To develope the surface of a cylinder contained between two other concentric cylindric surfaces and a plane, in such a manner, that the axes of the two cylindric surfaces may cut the axis of the first cylinder at right-angles, and that the plane may pass along the axis of the first cylinder, and cut the axis of the two cylinders at right-angles, i. 387.
To develope that portion of the surface of a cone contained between two parallel planes and a third plane, so that the axes of the cone may be cut at right-angles by the parallel planes, and that the third plane may pass along the axis of the cone, i. 387.
To develope that portion of the surface of a cone contained between two concentric cylindric surfaces, and a plane passing along the axis, so that the plane may cut the common axis of the cylindric surfaces at right-angles, i. 387.
To develope the surface of a cuneoid contained between two parallel planes, and a plane passing along the axis of the cuneoid, so that the parallel planes may be perpendicular to the plane passing along the axis, the section of one of the parallel planes being given, i. 387.
To develope that portion of the surface of a cuneoid terminated on two sides by a plane passing through the axis, and by two concentric cylindric surfaces, whose axis is perpendicular to the plane given; given, that portion of the plane terminated by the curved surface of the cuneoid, and by the intersections of the two cylindric surfaces, also the semicircular section of the cuneoid, i. 388.
Of finding the envelopes of solids by means of points, i. 388.
EPHESUS, i. 388.
Description of, i. 388.
EPICYCLOID, i. 388.
Description, i. 388.
Of division into two kinds, i. 389.
Dr. Halley's proposition for measuring, i. 389.
Determination of area of, i. 389.
" tangent of, i. 389.
Of different writers on the subject, i. 389.
EPISTYLE, i. 389.
EPISTYLAR ARCUATION, i. 389.
EPITITHEDAS, i. 389.
EQUAL ANGLES, i. 389.
EQUAL ARCS, i. 389,
Arcs, i. 11.
EQUAL CIRCLES, i. 389.
EQUAL CURVATURES, i. 389.
Curvature, i. 219.
Curve, i. 219.
EQUAL FIGURES, i. 389.
EQUAL SOLIDS, i. 389.
EQUIANGULAR FIGURES, i. 389.
EQUIDISTANT STRAIGHT LINES, i. 389.
EQUIDISTANT SOLIDS, i. 389.
EQUILATERAL, i. 389.
EQUILATERAL FIGURES, i. 389.
EQUILATERAL HYBERBOLA, i. 389.
EQUILIBRIUM, i. 389.
ERGASTULUM, i. 389.
ESCAPE, i. 389.
ESCUTCHEON, i 389.
ESCURIAL, i. 389.
Description of, i. 389.
ESTIMATE, i. 390.

Brickwork, i. 49.
Carpenter's Work, i. 78.
Joiner's Work, ii. 70.
ESTIMATION, i. 390.
ESTRADE, i. 390.
ETRUSCAN ARCHITECTURE, i. 390.
History of the Etruscans, i. 390.
Of the difficulty of arriving at any correct information, i. 390.
Of ruins at Cortona, Volterra, and Fiesol, i. 391.
Description of Etruscan temples, i. 390.
" Sepulchral buildings, i. 390.
" Cemeteries at, i. 391.
Vulci, i. 391.
Norchia, i. 391.
Castle d'Asso, i. 391.
Bornazzo, i. 391.
Arte, i. 381.
Tombs of Porsenna, i. 391.
Roman Architecture, ii. 370.
EUANTHI COLOURS, i. 392.
EVOLVENT, i. 392.
EVOLUTE, or EVOLUTA, i. 392.
EURYTHMY, i. 392.
EUSTYLE, i. 392.
EXAGON, i. 392.
Hexagon, i. 495.
EXCAVATING MACHINES, i. 392.
Description of Mr. G. V. Palmer's, i. 392.
EXCAVATION, i. 393.
Digging, i. 268.
Foundation, i. 429.
EXCHANGE, i. 393.
Use of in London, i. 393.
Corn Exchange, i. 393.
Description of, i. 393.
The colonnade, i. 393.
Decorations of the frieze, i. 393.
The cornice, i. 394.
The wings, i. 394.
The windows, i. 394.
Upper story of wings, i. 394.
Interior, i. 394.
Coal Exchange, i. 394.
Supply of coal in Great Britain, i. 394.
Site of Coal Exchange, i. 394.
Façades of the building, i. 394.
Tower " , i. 394.
Dome " , i. 395.
Floor " , i. 395.
Desiccation, i. 265.
Coloured decorations, i. 395.
Royal Exchange, i. 395.
Origin of first building, i. 396.
Of the architect of the second, i. 396.
Description of second exchange, i. 396.
On architectural competitions, i. 397.
Of the plans and specifications sent in for the building of the present Royal Exchange, i. 397.
Extent and site of do., i. 398.
Arrangement, i. 398.
Accommodation, i. 399.
Style of architecture, i. 400.
Estimate, i. 401.
Income, i. 401.
On the roofing in of the area, i. 401.
Stone employed in construction, i. 402.
Antiquities discovered, i. 402.
Opening, i. 402.
Sculpture in pediment, &c., i. 403.
EXEDRÆ, i. 403.
EXENTRIC or ECCENTRIC, i. 403.
EXOSTRA, i. 403.
EXPANSION, i. 403.
Table of expansion of various materials, i. 404.
EXPERIENCE, i. 405.
EXPERIMENT, i. 405.
EXPERIMENTAL PHILOSOPHY, i. 405.
Treatise on nature and history of, i. 405.
EXPLOSION, i. 409.
Treatise upon, i. 409.
Directions to be generally observed in blasting, i. 409.
EXPONENT, i. 409.
EXPONENTIAL CURVES, i. 409.
EXPOSURE, i. 409.
EXTEND, i. 409.
EXTENSION, i. 409.
Definition of, i. 409.
Of the boundaries of lines, surfaces, and solids, i. 410.
Of the infinite divisibility of extension, i 410.
EXTERNAL, or EXTERIOR, i. 411.
EXTERNAL, or EXTERIOR ANGLES, i. 411.
Angles, i. 6.
EXTRADOS, i. 411.
Arch, i. 13.
Bridge, i. 58.
EXTREME, i. 411.
EYE, i. 411.
EYE, BULLOCK'S, i. 411.
EYE OF A DOME, i. 411.
EYE OF A VOLUTE, i. 411.
Spiral, ii. 440.
Volute, ii. 520.
EYE, *in perspective*, i. 411.
EYE-BROW, i. 411.
Fillet, i. 414.

FABER, i. 411.
FABRIC, i. 411.
FACADE, or FACE, i. 411.
FACE, or FACIA, i. 412.
Fascia, i. 413.
FACE MOULD, i. 412.
FACE OF A STONE, i. 412.
FACET, or FACETTE, i. 412.
FACIA, i. 412.
Fascia, i. 413.
FACING, *in Engineering*, i. 412.
FACING, i. 412.
FACING FACADE, or REVETEMENT, i. 412.
FACINGS, *in Joinery*, i. 412.
FACTABLING, i. 412.
Coping, i. 199.
FAIR CURVE, i. 412.
FAHRENHEIT, i. 412.
FALD STOOL, i. 412.
FALL, i. 412.
Measure, ii. 130.
Weights and Measures, ii. 523.
FALLING MOULDS, i. 412.
FALLING SLUICES, i. 412.
FALSE ROOF, i. 412.
FANE, i. 412.
Vane, ii. 515.

Fan-shaped Window, i. 412.
Fan-tracery Vaulting, i. 412.
Fanum, i. 412.
Fanum Jovis, i. 412.
Farm, i. 412.
Fascia, Facia, or Face, i. 413.
Fascine, i. 413.
Fastigium, i. 413.
Pediment, ii. 270.
Fathom, i. 413.
Faux, i. 413.
Favissa, i. 413.
Feather-edged Boards, i. 413.
Feather-edged Coping, i. 413.
Coping, i. 199.
Feathering, i. 413.
Foliation, i. 418.
Feeder, i. 413.
Feeding House, or Shed, i. 413.
Felling, i. 413.
Felt Grain, i. 413.
Felting, i. 413.
Femur, i. 413.
Fence, i. 413.
Fence of a Plane, i. 413.
Fenestella, i. 413.
Piscina, ii. 298.
Credence Table, i. 212.
Chancel, i. 141.
Fenestration, i. 413.
Feretory, i. 413.
Festoon, i. 413.
Fetching the Pump, i. 413.
Figure, i. 413.
Figure, *in Geometry*, i. 413.
Figure, *in Architecture*, i. 414.
Figure, *in Conics*, i. 414.
Figure, *in Fortification*, i. 414.
Circumscribed, i. 164.
Inscribed, ii. 12.
Equal, i. 389.
Equilateral, i. 389.
Similar, i. 430.
Regular, ii. 361.
Irregular, ii. 39.
Figure of the Diameter, i. 414.
Fillet, i. 414.
Fillet, *in Carpentry or Joinery*, i. 414.
Fillet Gutter, i. 414.
Guttering, i. 483.
Filling in Pieces, i. 414.
Fine Set, i. 414.
Fine Stuff, i. 414.
Plastering, ii. 307.
Finial, i. 414.
Finishing, i. 414.
Finishing, *in Plastering*, i. 414.
Plastering, ii. 307.
Fir, i. 414.
Timber, ii. 491.
Fir, wrought, i. 414.
" wrought and framed, i. 414.
" wrought, framed, and rebated, i. 414.
" wrought, framed, rebated, and beaded, i. 414.
Fir Boards, i. 414.
Deal, i. 227.
Fir-framed, i. 414.
Fir in Bond, i. 414.
Fir Poles, i. 414.
Fir-no-Labour, i. 414.
Fire Bricks, i. 414.
Brick, i. 47.
Fire Engine, i. 414.
Fire Escape, i. 414.
Fire Place, i. 414.
Fire-proof Houses, i. 414.
On the roofs of, i. 414.
On the floors of, i. 415.
On the necessity of making all houses fire proof, i. 415.
On the use of iron, i. 415.
Fire Stone, i. 415.
Firmer, i. 415.
Former, i. 415.
Furmer, i. 415.
Tools, ii. 494.
Fish Pond, i. 415.
Fistuca, i. 415.
Fixed Axis, i. 415.
Fixed Points, i. 415.
Flags, i. 415.
Flake White, i. 415.
Flamboyant, i. 415.
Description of, i. 415.
Flank, i. 415.
Flank Walls, i. 415.
Flaps, i. 415.
Flashed, i. 415.
Flashings, i. 415.
Flat Crown, i. 415.
Corona, i. 205.
Flatting, i. 415.
Flemish Bond. i. 416.
Bricklaying, i. 48.
Flemish Bricks, i. 416.
Flexure, or Flexion, i. 416.
Flight, i. 416.
Flight, Leading, i. 416.
Staircasing, i. 441.
Flight, Returning, i. 416.
Staircasing, i. 441.
Float, i. 416.
Plastering, ii. 307.
Float Boards, i. 416.
Float Stone, i. 416.
Bricklayers, i. 47.
Floated Lath and Plaster, i. 416.
Plastering, ii. 307.
Floating Rendered and Set, i. 416.
Plastering, ii. 307.
Floating, i. 416.
Plastering, ii. 307.
Floating Bridge, i. 416.
Bridge, i. 63.
Floating Rules, i. 416.
Plastering, ii. 307.
Floating Screeds, i. 416.
Plastering, ii. 307.
Flood Gate, i. 416.
Floor, i. 416.
Seasoning of wood for, i. 416.
Laying of best floors, i. 416.
Of folded floors, i. 416.
Of dowelled do., i. 416.
Measurement of flooring, i. 417.

Carcase Flooring, i. 77.
Naked do., ii. 224.
Floor Joists, or Flooring Joists, i. 417.
Floors of Earth, or Earthen Floors, i. 417.
Construction of, i. 417.
Different kinds of, i. 417.
Flooring Cramp, i. 417.
Flooring Machine, i. 417.
Floor Timbers, i. 417.
Florid Style, i. 417.
Gothic Architecture, i. 460.
Flue, i. 417.
Chimney, i. 144.
Flush, i. 418.
Flush, *in Masonry*, i. 418.
Flush and Bead, i. 418.
Bead and Flush, i. 33.
Flutes, or Flutings, i. 418.
Of fillets, i. 418.
Fluting in different orders of Architecture i. 418.
Column, i. 179.
Cable, i. 73.
Fluxions, i. 418.
Flyers, i. 418.
Flying Bridge, i. 418.
Bridge, i. 63.
Flying Buttresses, i. 418.
Buttress, i. 67.
Focus, i. 418.
Ellipsis, i. 365.
Hyberbolic Curve, i. 515.
Parabolic Curve, i. 260.
Fodder, Futher, or Fother, i. 418.
Foils, i. 418.
Cusp, i. 220.
Foliation, i. 418.
Folded Floor, i. 418.
Floor, i. 416.
Folding Doors, i. 418.
Folding Joint, i. 418.
Folds, or Flaps, i. 418.
Foliage, i. 418.
Ornaments, ii. 245.
Foliation, i. 418.
Foils, i. 418.
Font, i. 418.
Of baptisteries, i. 418.
Materials for construction of fonts, i. 419.
Various specimens of, i. 419.
Fontana, Dominic, i. 419.
Foot, i. 419.
Of the lineal foot, i. 419.
Measures, ii. 132.
Of the square foot, i. 419.
Of the cubic or solid foot, i. 419.
Value of the foot in different countries, i. 420.
Foot Bank, or Foot Step, i. 420.
Foot Base, i. 420.
Foot Bridge, i. 420.
Bridge, i. 58.
Foot of the Eye Director, i. 420.
Foot of a Vertical Plane, i. 420.
Foot Irons, i. 420.
Foot Pace, i. 420.
Staircasing, ii. 441.
Foot Stall, i. 420.
Footing Beam, i. 420.
Footings, i. 420.
Footing Dormant, i. 420.
Force, i. 420.
Definition of, i. 420.
Vis viva and mortua, i. 420.
Force measured by velocity, i. 421.
Composition of forces, i. 421.
Principle of the lever, i. 422.
Virtual velocity, i. 422.
Conservation of the vis viva, i. 423.
" of the motion of the centre of gravity, i. 424.
" of equal areas, i. 424.
" of least action, i. 424.
Forces instantaneous, i. 425.
" continued uniform, i. 425.
" variable, i. 425.
Immediate force of men, i. 426.
Performance of men by machines, i. 426.
Force of horses, i. 426.
Inanimate force, i. 427.
Fore Front, i. 427.
Fore Ground, i. 427.
Fore Plane, i. 427.
Tools, i. 494.
Fore-shorten, i. 427.
Foreign, i. 427.
Forge, i. 427.
Form, i. 427.
Figure, i. 413.
Form, *in Joinery*, i. 427.
Formerets, i 427.
Form Pieces, i. 427.
Fort, i. 427.
Fortalice, i. 427.
Fornix, i. 427.
Arch, i. 12.
Vault, ii. 515.
Forum, i. 427.
Description of by Vitruvius, i. 427.
On the different kinds of foræ, i. 428.
On the Forum Romanum, i. 428.
Of the Julian Forum, i. 428.
Augustus's Forum, i. 428.
Nerva's do., i. 428.
Trajan's do., i. 428.
Forum of Pompeii, i. 428.
Forum of Constantinople, i. 429.
Fosse, i. 429.
Fosses d'Aisances, i. 429.
Description of, i. 429.
Sewerage, ii. 413.
Sewer, ii. 413.
Foundation, i. 429.
Palladio on, i. 429.
Bricklaying, i. 47.
Concrete, i. 186.
On piling, i. 429.
Proportionate dimensions of foundations, i. 430.
Fountain, i. 430.
Fox-tail Wedging, i. 430.
Fraction, i. 430.
Decimal, i. 228.
Frame, i. 430.
Floor, i. 416.
Naked Flooring, ii. 224.
Partition, ii. 264.

Truss, ii. 508.
Truss Partition, ii. 509.
FRAME, *in Joinery*, i. 430.
FRAMING, i. 430.
FRANKING, i. 430.
FRATERY, or FRATER HOUSE, i. 430.
Refectory. ii. 361.
FREEMASON, i. 430.
FREEDSTOOL, FRIDSTOOL, or FRITHSTOOL, i. 430.
FREE STONE, i. 430.
Stone, ii. 449.
FREE STUFF, i. 430.
FREEZE, i. 430.
Frieze, i. 434.
FRENCH CASEMENTS, i. 430.
FRESCO PAINTING, i. 431.
Description of, i. 431.
Of the walls and preparation of grounds, i. 431.
Sketch and cartoon, i. 431.
Preparations for colouring, i. 432.
List of colours used in, i. 432.
Antiquity of, i. 432.
Qualities to be sought in, i. 433.
Fresco decoration of Houses of Parliament, i. 433.
Do. in Buckingham Palace, i. 433.
Fine arts commission, i. 434.
Works by Italian artists, i. 434.
FRET, i. 434.
Entail, i. 387.
FRIARY, i. 434.
FRIEZE, or FRIZE, i. 434.
On the friezes of the different orders, i. 435.
Examples, i. 435.
FRIEZE, PANEL, i. 435.
FRIEZE, RAIL, i. 435.
FRIEZES, FLOURISHED, i. 435.
FRIEZES, HISTORICAL, i. 435.
FRIEZES, MARINE, i. 435.
FRIEZES, RUSTIC, i. 435.
FRIEZES, SYMBOLICAL, i. 435.
FRIEZE OF THE CAPITAL, i. 435.
Hypotrachelion, i. 516.
FRIGERATORY, i. 435.
FRIGIDARIUM, i. 435.
FRIZE, i. 435.
Frieze, i. 434.
FRONT, i. 435.
FRONTAGE, i. 435.
FRONTAL, i. 435.
FRONTON, i. 435.
FROSTED, i. 435.
FROWEY TIMBER, i. 435.
FRUSTUM, i. 435.
Description of, i. 435.
To measure the frustum of a square pyramid, i. 435.
To measure the frustum of a cone, i. 436.
FULCRUM, i. 436.
FUMARIUM, i. 436.
FUNNEL, i. 436.
Chimney, i. 144.
FURCATED, i. 436.
FURLONG, i. 436.
FURNITURE, i. 436.
FURRING, i. 436.
FURRINGS, i. 436.
FUR-UP, i. 436.
Furring, i. 436.
FUST, i. 436.
FUSTIC, i. 436.
FUSUROLE, or FUSAROLE, i. 436.

GABION, i. 437.
Description of, i. 437.
Use of, i. 437.
GABLE, i. 437.
Pediment, ii. 270.
Barge Boards, i. 27.
GABLE-ROOFED, i. 437.
GABLE WINDOW, i. 437.
GABLET, i. 437.
GAGE, i. 437.
Of the different kinds of gages, i. 437.
Of the common gage, i. 437.
" mortise and tenon gage, i. 437.
" internal gage, i. 437.
" flooring gage, i. 437.
GAIN, i. 437.
Tusk, ii. 514.
GALILEE, i. 437.
Description of, i. 437.
Examples of, i. 437.
Origin of the term, i. 437.
GALLERY, i. 437.
Description of, i. 437.
GANG-LADDER, i. 438.
GANG-WAY, i. 438.
GAOL, i. 438.
Rules respecting, i. 438.
Prison, ii. 323.
GARDE, PONT DU, i. 438.
Aqueduct, i. 11.
Bridge, i. 58.
GARDEN HANGING, i. 438.
Origin and description of, i. 438.
GARDEN SHEDS, i. 438.
GARGOYLE, GARGLE, GARGYLE, AND GURGOYLE, i. 438.
GARLANDS, i. 438.
GARNETS, i. 438.
GARRET, i. 438.
GARRETING, i. 438.
GARRISON, i. 438.
GATE, i. 439.
Door, i. 288.
GATE, *in Rural Economy*, i. 439.
GATE, *in Engineering*, i. 439.
GATE-HOUSE, i. 439.
Description of, i. 439.
Examples of, i. 439.
GATE-WAY, i. 439.
GATHERING OF THE WINGS, i. 439.
GAVEL, i. 439.
Gable, i. 437.
GAUGE, i. 439.
Gage, i. 437.
GEMMEL, GYMMER, or CHYMOL, i. 439.
GENERATING LINE, or PLANE, i. 439.
GENESIS, i. 439.
GENTESE, i. 439.
GEODESY, i. 439.
GEOLOGY, i. 439.
GEOMETRICAL, i. 439.
GEOMETRICAL LOCUS, or PLACE, i. 439.
Locus, ii. 109.
GEOMETRICAL PACE, i. 439.

Geometrical Plan, i. 439.
Plan, ii. 299.
Geometrical Plane, i. 439.
Geometrical Solution of a Problem, i. 439.
Geometrical Stair, i. 440.
Geometry, i. 440.
" history of, i. 440.
" use of, i. 441.
" theoretical and practical, i. 441.
Conic Sections, i. 189.
Ellipse, i. 365.
Descriptive Geometry, i. 237.
To erect and drop a perpendicular, i. 441.
To draw parallels at a given distance, i. 442.
To bisect a right line by a perpendicular, i. 442.
To make an angle equal to a given angle, i. 442.
To bisect an angle, i. 442.
To bisect an arc of a circle, i. 442.
Given a circle and tangent to find the point of contact, i. 442.
To draw a tangent through a given point, i. 442.
To inscribe a chord in a circle equal to a given line, i. 442.
To inscribe an equilateral triangle in a circle, i. 442.
" a square " , i. 442.
" a pentagon " , i. 442.
" a hexagon " , i. 442.
Upon a given straight line to describe—
" an equilateral triangle, i. 442.
" a square, i. 442.
" a pentagon, i. 442.
" a hexagon, i. 442.
" an octagon, decagon, and dodecagon, i. 442.
To describe a circle passing through three given points, i. 443.
To describe a circle of a given radius, through two given points, i. 443.
To describe a circle through two points, and touching a straight line, i. 443.
Ditto, through one point, and touching two straight lines, i. 443.
" to touch three straight lines, i. 443.
" to touch a straight line at a given point, and pass through another point, i. 443.
" to touch two straight lines, one of them at a given point, i. 443.
" to touch a circle, and a straight line at a given point, i. 443.
" with a given radius to touch a given circle, and pass through a given point, i. 443.
" in a given sector, i. 443.
In a given circle to describe any number of equal parts, i. 443.
To find a fourth proportional, i. 443.
To divide a line in a given proportion, i. 443.
To find a mean proportional, i. 444.
To divide a straight line harmonically in a given ratio, i. 444.
To describe a triangle with given sides, i. 444.
Ditto, the base being given, as also the ratio of the two other sides, and an angle, i. 444.
To make a rectilinear figure equal and similar to a given rectilinear figure, i. 444.
To make a quadrilateral similar to a given figure upon a given line, i. 444.
Two adjoining sides of a parallelogram being given, to complete the figure, i. 444.
Ditto, of a rectangle ditto, i. 444.
Given the diagonal and one of the sides of a rectangle to complete the figure, i. 444.
To make the triangle equal to a trapezium, i. 444.
Ditto, to any given right-lined figure, i. 444.
To reduce a triangle to a rectangle, i. 444.
One side being given, to make a rectangle equal to a given rectangle, i. 444.
Given one of its angles to make a parallelogram equal to a given parallelogram, i. 444.
To make a square equal to a rectangle, i. 444.
" equal to two or three given squares, i. 445.
Given the chord and height to describe the segment by a trammel, i. 445.
Given a trapezium and a point in one of its sides to find the points in its other sides, which would touch an inscribed ellipse, i. 445.
" to find the centre of an inscribed ellipse touching the side at the given point, i. 446.
" to find two axes of an inscribed ellipse to pass through the given point, i. 446.
Giblea Cheque, Giblet Check, or Giblet Cheek, i. 446.
Gigantic Order, i. 446.
Gilding, i. 446.
Gill, i. 446.
Gimlet, or Gimblet, i. 446.
Ginæconites, i. 446.
Giocondo, i. 446.
Girandole, i. 446.
Girder, i. 446.
Of girders for floors, i. 446.
Rules for finding scantlings of, i. 446.
Trussing of girders, i. 447.
Girding Beam, i. 447.
Girder, i. 446.
Girdle, i. 447.
Girt, i. 447.
Fillet, i. 414.
Girt, *in timber measure*, i. 447.
Given Datum, i. 447.
Glacis, i. 447.
Glass, i. 447.
History of, i. 447.
Different qualities of, i. 447.
Crown glass, i. 447.
Plate glass, i. 447.
Of glass pipes, i. 448.
" tiles, i. 448.
Stained Glass, ii. 441.
Glazing, i. 448.
Tools for, i. 448.
Diamond, i. 267.
Fretwork, i. 449.
Globe, i. 449.
Sphere, ii. 439.
Glue, i. 449.
Directions for making, i. 449.
Austin's patent cement, i. 449.
Glyph, i. 449.
Gneiss, i. 449.
Gobelin, i. 449.
Gnomonic Column, i. 450.
Column, i. 183.
Gnomonic Projection of the Sphere, i. 450.
Gocciolatoio, i. 450.
Corona, i. 205.
Gola, Gola-diretta, Gola-Rovescia, i. 450.

Cymatium, i. 225.
GOLDMAN, i. 450.
GONIOMETER, i. 450.
GONIOMETRICAL LINES, i. 450.
GORGE, i. 450.
GORGERIN, or GORGE, i. 450.
GOTHIC ARCHITECTURE, i. 450.
Upon the general acceptation of the term, i. 450.
Pointed Architecture, ii. 315.
On the substitution of the terms Christian, Catholic, English, and Pointed, in lieu of that of Gothic, i. 451.
Sir James Hall thereon, i. 451.
On the prejudices held by many against this style, i. 452.
Quotations on this subject from—
Wren's Parentalia, i. 452.
Rev. J. Milner, i. 453.
Bishop Warburton, i. 453.
Mr. Dallaway, i. 453.
Mr. Coleridge, i. 453.
Mr. Whewell, i. 453.
Mr. Poole, i. 453.
Mr. Pugin, i. 453.
On the principles upon which the excellence of the Gothic style depends,—quotations from Mr. Poole, i. 454.
Of the scientific skill exhibited in construction of Gothic vaults, &c., i. 455.
Such construction compared with that by Wren, in St. Paul's, London, i. 456.
On the architectural propriety of this style, i. 456.
Application of ornament, i. 456.
Convenience and accommodation, i. 456.
Introduction of grouping, i. 457.
On the applicability of this style to any plan, i. 457.
Comparisons between the Grecian and Gothic styles, i. 458.
On the styles which preceded the Gothic, i. 458.
Tabular comparison of the Classic and Gothic styles, i. 458.
Classification of examples of this style by—
Warton, i. 460.
Mr. Dallaway, i. 460.
Rickman, i. 460.
Mr. Bloxam and others, i. 460.
Of the difficulty of classification, i. 460.
On Mr. Willis's nomenclature, i. 460.
The impost, i. 460.
Continuous imposts, i. 460.
Discontinuous do., i. 460.
Corbelled do., i. 460.
Arches simple and compound, i. 460.
Shafted archways, i. 460.
Banded do., i. 460.
Vaulting shafts, i. 460.
Bearing shafts, i. 460.
Sub " , i. 460.
Face " , i. 460.
Edge " , i. 460.
Nook " , i. 461.
Sub-arch, i. 461.
Face " , i. 461.
Edge " , i. 461.
Nook " , i. 461.
Foiled arch, i. 461.
Foliated " , i. 461.
Longitudinal do. in vaulting, i. 461.
Transverse do., i. 461.
Diagonal do., i. 461.
Building pillars, i. 461.
Pilaster masses, i. 461.
Quadripartite vaulting, i. 461.
Sexpartite do., i. 461.
Octopartite do., i. 461.
Groins, i. 461.
Ridges, i. 461.
Groin ribs, i. 461.
Ridge " , i. 461.
Surface " , i. 461.
Of the arches in use in the mediæval buildings, i. 461.
Early English style, i. 461.
Description of the different parts of a building in this style, i. 462.
Arches, i. 462.
Piers, i. 464.
Capitals, i. 462.
Windows, i. 462.
Dripstones, i. 463.
Doorways, i. 463.
Doors, i. 463.
Buttresses, i. 463.
Flying buttresses, i. 463.
Parapets, i. 463.
Pinacles, i. 464.
Roofs of stone and timber, i. 464.
Tie beams, i. 464.
Towers, i. 464.
Mouldings, i. 464.
Sculptured foliage, i. 465.
Walls, i. 465.
Niches, i. 465.
Description of the decorated style in form and manner as above, i. 465.
Of the perpendicular style, ditto ditto., i. 468.
Of the Debased style, i. 471.
Church, i. 151.
Cathedral, i. 115.
Ecclesiastical Architecture, i. 312.
GOUFING FOUNDATIONS, i. 471.
GOUGE, i. 471.
GOWT, or GO OUT, i. 471.
GRACES, GRATIÆ, or CHARITIES, i. 471.
Description of, i. 471.
Various representations of, i. 472.
Temples dedicated to, i. 472.
GRADATION, *in Architecture*, i. 472.
GRADATION, *in Painting*, i. 472.
GRADETTO, GRADETTI, ANNULI, i. 472.
Annulets, i. 7.
GRADIENT, i. 472.
GRAFTING TOOL, i. 472.
GRAIN, i. 472.
GRAIN, *in Mining*, i. 472.
GRANARY, i. 472.
Construction of, Mr. Bruyere on, i. 472.
Directions for construction of in this country, i. 473.
GRAND STAIRCASE, i. 473.
Staircase, ii. 441.
GRANGE, i. 473.
GRANITE, i. 474.
Uses and durability of, i. 474.
Granite, gray of Chessi, i. 474.
" gray of Thain, i. 474.
" gray of Lavezzi, i. 474.
" gray of Elba, i. 474.

Granite, antique green, i. 474.
" fine-grained antique, i. 474.
" of St. Christophe, i. 474.
" Corsican orbicular, i. 474.
" red of Ingria, i. 475.
" red of the Vosges Mountains, i. 475.
" violet of Elba, i. 475.
" rose-coloured of Beveno, i. 475.
" graphic of Portsoy, i. 475.
" " Siberia, i. 475.
" " Autun, i. 475.
" " Corsica, i. 475.
Quarry, ii. 351.
Materials, ii. 126.
GRATICULATION, i. 475.
GRAVITY, i. 475.
Specific Gravity, ii. 438.
GREAT CIRCLE OF A SPHERE, i. 475.
GREAT STAIRCASE, i. 475.
Grand Staircase, i. 473.
GREEK ARCHITECTURE, i. 475.
Greek Orders, i. 475.
Architecture, i. 15.
Roman Architecture, ii. 370.
GREEK CROSS, i. 475.
Cross, i. 213.
GREEK MASONRY, i. 475.
Masonry, ii. 117.
Walls, ii. 522.
GREEK MOULDINGS, i. 475.
Mouldings, ii. 221.
GREEK ŒCUS, i. 475.
Œcus, ii. 243.
GREEK ORDERS, i. 475.
Doric, i. 290.
Ionic, ii. 18.
Corinthian, i. 200.
Orders, ii. 244.
Architecture, i. 14.
GREEK ORNAMENTS, i. 475.
Ornaments, ii. 245.
GREENING, i. 475.
GREEN-HOUSE, i. 475.
Of former modes of construction, i. 475.
Conservatory, i. 191.
Difference between green-houses and conservatories, i. 475.
Situation and dimensions of, i. 476.
Construction of, i. 476.
GRIFFIN, or GRIFFON, i. 476.
GRILLAGE, i. 476.
GRINDSTONE, i. 476.
GRINDING, i. 476.
GRIT STONE, i. 476.
Stone, ii. 449.
Whetstone, ii. 525.
GRIT STONE, *in Mining*, i. 477.
Sand Stone, ii. 398.
GROIN, i. 477.
Definition of, i. 477.
Origin of, i. 477.
Treatment of, i. 477.
Use of groins in constructing warehouses, and such like buildings, i. 178.
Construction of groins, i. 478.
Explanation of plates, i. 479.
GROIN CEILING, i. 479.
Ellipsis, i. 365.
GROIN, or GROYNE, *in Engineering*, i. 480.
Examples at Eastbourne, i. 480.
Rules for construction of, i. 480.
GROOVE, i. 481.
GROTESQUE, i. 481.
Description of, i. 481.
Origin of, i. 481.
GROTTO, i. 481.
Description of, i. 481.
Cement for, i. 481.
To make artificial coral branches, i. 481.
GROUND CILL, i. 482.
Ground Sill, i. 482.
GROUND JOISTS, i. 482.
GROUND LINE, i. 482.
Ground Plane, i. 482.
GROUND NICHE, i. 482.
GROUND PLAN, i. 482.
GROUND PLANE, i. 482.
GROUND PLATE, i. 482.
Ground Sill, i. 482.
GROUND PLOT, i. 482.
GROUND RENT, i. 482.
GROUND SILL, or GROUND PLATE, i. 482.
GROUND TABLE, i. 482.
GROUND WORK, i. 482.
Foundation, i. 429.
GROUNDS, i. 482.
GROUP, i. 482.
GROUPED COLUMNS, or PILASTERS, i. 482.
GROUT, i. 482.
GRY, i. 482.
GUARDS, i. 482.
GUERITE, i. 482.
GUILD HALL, or GILD HALL, i. 482.
GUILLOCHI, i. 482.
GULA, or GUEULE, i. 482.
Cymatium, i. 225.
GULBE, i. 482.
Gorge, i. 450.
GULLIES, i. 482.
GULOICK, i. 482.
Impost, ii. 2.
GUNTER'S CHAIN, i. 482.
GURGOYLE, i. 482.
Gargoyle, i. 438.
GUTTÆ, i. 482.
GUTTER, i. 482.
Definition of, i. 482.
Construction of, i. 483.
Metropolitan Building Act on, i. 438.
GUTTERING, i. 483.
Gutter, i. 482.
GUTTERS, i. 483.
GYMNASIUM, i. 483.
Description of, i. 483.
Nature of exercises practised therein, i. 484.
GYNÆCEUM, i. 484.
GYPSOGRAPHY, i. 484.
GYPSUM, i. 484.
Plaster of Paris, i. 484.
Kilns for burning, i. 484.
Of Scagliola, 484.
Alabaster, i. 485.
Gypseous alabaster, i. 485.
Calcareous do., i. 485.

Mode of taking models from sulphureous springs, whose waters are impregnated with Gypsum, i. 485.

Hacking, i. 486.
Half-Moon, i. 486.
Ravelin, ii. 360.
Half-Round, i. 486.
Half-Space, or Pace, i. 486.
Half Teint, i. 486.
Treatise on, i. 486.
Half-Timbered Houses, i. 486.
Hall, i. 486.
Tetrastyle, i. 486.
Corinthian, i. 486.
Egyptian, i. 486.
Dimensions of, i. 486.
Examples of in England, i. 487.
Hall, different kinds of, i. 487.
Halving, i. 487.
Ham, i. 487.
Hammer, i. 487.
Hammer Beam, i. 487.
Hances, or Haunches, i. 487.
Hand, i. 487.
Hand Irons, i. 487.
End Irons, i. 386.
Hand-rail, i. 487.
Hand-railing, i. 487.
Principles adopted in finding moulds, i. 487
Nosings of steps, i. 488.
Flyers and winders, i. 488.
Of helical solids, i. 488.
Method of forming a helical line, i. 489.
Technical expressions, i. 489.
To construct the falling and face-moulds of a rail to a level landing, so as to have the grain of the wood parallel, i. 490.
To construct the face-mould of a rail to a stair upon a level landing, in two parts, round a semi-circular newel, so that the fibres of the wood may mitre at the joint, i. 491.
To spring the plank for a level landing through two given points, so as to parallel the grain, i. 491.
To draw the scroll of a hand-rail, and to find the mould for executing the twist, i. 491.
To find the face-mould for the shank of the scroll, i. 492.
To find the falling mould, i. 492.
The method of forming the curtail of the first step, i. 492.
To describe the section of a rail of the usual dimensions, i. 492.
To describe the mitre cap of a rail, i. 493.
Hanging, i. 493.
Hinging, i. 495.
Hanging Style, i. 493.
Hangings, i. 493.
Hangs-over, i. 493.
Hard Bodies, i. 493.
Definition of Term, i. 493.
Hard, i. 493.
Hard Finishing, i. 493.
Plastering, ii. 307.
Hardening of Timber, i. 493.
Timber, ii. 489.
Seasoning of Timber, ii. 410.
Harmonic, or Harmonical Proportion, i. 493.
Harmony, i. 493.
Harness Room, i. 493.
Hasp, i. 493.
Hatchway, i. 493.
Hatchet, i. 493.
Haunch, i. 493.
Head, i. 493.
Head, Jerkin, i. 493.
Jerkin Head, ii. 55.
Header, i. 493.
Heading Course, i. 493.
Bricklaying, i. 49.
Heading Course, i. 493.
Heading Joint, i. 493.
Headway of a Stair, i. 494.
Hearse, or Herse, i. 494.
Heart Bond, i. 494.
Masonry, ii. 119.
Walls, ii. 522.
Hearth, i. 494.
Chimney, i. 144.
Heather Roof, i. 494.
Hecatompedon, i. 494.
Hecatonstylon, i. 494.
Heck, i. 494.
Heel, i. 494.
Heel of a Rafter, i. 494.
Height, i. 494.
Helicoid Parabola, or Parabolic Spiral, i. 494.
Heliopolis, or the City of the Sun, Description of, i. 494.
Egyptian Architecture, i. 351.
Helix, i. 494.
Helmet, i. 494.
Hem, i. 494.
Hemi, i. 494.
Hemicycle, i. 494.
Hemicyclium, i. 494.
Hemisphere, i. 494.
Hemispheroidal, i. 494.
Hemitriglyph, i. 494.
Hendecagon, Endecagon, or Undecagon, i. 494.
Heptagon, i. 494.
Heptagonal, i. 495.
Herbosum Marmor, i. 495.
Herring Bone, i. 495.
Saxon Architecture, ii. 406.
Hermogenes, i. 495.
Hewn Stone, i. 495.
Hexaedron, or Hexahedron, i. 495.
Cube, i. 216.
Hexagon, i. 495.
Hexastyle, i. 495.
Hindoo Architecture, i. 495.
Indian Architecture, ii. 2.
Hinges, i. 495.
Hinging, i. 495.
Hinges for various joints, i. 495.
Various methods of hanging doors, &c., i. 495.
Hip, i. 496.
Hip-Roof, i. 496.
Hip-Knob, i. 496.
Hip-Mould, i. 496.
Hip-Roof, i. 496.
Description of various parts, i. 496.
Given the plan of the building, and pitch of the roof, to find the various lengths and angles concerned, whether the roof is square or bevel, i. 497.
Hippium, i. 499.
Hippodrome, i. 499.
" The Olympian, i. 499.

Hippodrome at Constantinople, i. 499.
" near Stonehenge, i. 500.
Historical Columns, i. 500.
Column, i. 183.
Hoarding, i. 500.
Hoist, i. 500.
Hollow, i. 500.
Hollow Bricks, i. 500.
Hollow Newell, i. 500.
Hollow Wall, i. 500.
Hollow Quoins, i. 500.
Homeshall, or Homestead, i. 500.
Homologous, i. 500.
Hood-mould, i. 500.
Label Moulding, ii. 90.
Weather Moulding, ii. 522.
Hook Pins, i. 500.
Draw-Bore Pins, i. 305.
Hooks, i. 500.
Hording, i. 500.
Hoarding, i. 500.
Horizontal Cornice, i. 500.
Horizontal Line, i. 500.
Horizontal Plane, i. 500.
Horizontal Projection, i. 500.
Horn, i. 500.
Horse Path, i. 500.
Horse Run, *in Engineering*, i. 500.
Horsing Block, i. 500.
Hospital, i. 500.
Hostel, or Hotel, i. 500.
Hot-house, i. 500.
History of, i. 501.
Conservatory, 191.
Situation of, i. 501.
Dimensions of, i. 501.
Construction of, i. 501.
Of the flues, i. 502.
Of the glazing, i. 502.
Hovel, i. 503.
Hovelling, i. 503.
House, i. 503.
Directions as to situation and construction, i. 503.
Building, i. 65.
Description of private dwellings of the ancients, i. 504.
Of private and public apartments of houses, and of their construction, according to different ranks of people, from Vitruvius, i. 504.
Of country-houses, with the description and uses of their several parts, from the same, i. 504.
Of the disposition of the houses of the Greeks, i. 505.
Extracts from Pliny's letters—description of villa at Laurentinum, i. 506.
Pliny's description of summer villa in Tuscany, i. 508.
Houses of the Jews, Greeks, and Romans, i. 510.
Examples of Roman houses, i. 510.
Description of villa discovered at Bignor, Sussex, i. 510.
House-building of the Britons, i. 512.
Description of Norman keep at Conisborough, i. 512.
" of the Edwardian castles, i. 512.
" of the castles of the 14th century, i. 512.
Of houses prior to 13th century, i. 512.
Example of do., i. 512.
Of houses at the close of the 13th century, i. 512.
Examples of at Little Wenham Hall, Suffolk, and The Mote, Ightam, Kent, i. 512.
Timber houses of this date, i. 512.
Castles and manor-houses of 15th century, i. 512.
Examples of, i. 513.
Examples of houses of 16th century, i. 513.
Examples of houses of 17th century, i. 513.
Early English houses of timber, i. 513.
Introduction of stone and brick, i. 513.
Internal walls, tapestry, floors, &c., i. 513.
Fire-places, i. 513.
Windows, i. 513.
Tudor Architecture, ii. 509.
Building Act regulations respecting houses, i. 514.
Housing, i. 514.
Hovelling, i. 514.
Hue, i. 514.
Humeri, i. 514.
Hundred of Lime, i. 514.
" great, or standard, i. 514.
" long, or northern, i. 514.
Hung, *Double*, i. 514.
Double Hung, i. 303.
Hunting Towers, i. 514.
Hurlers, i. 514.
Celtic Architecture, i. 124.
Hurries, i. 514.
Hut, i. 514.
Hut, *in Rural Economy*, i. 514.
Hypæthral Temple, i. 514.
Hypæthron, or Hypæthros, i. 514.
Hyperbola, i. 515.
Properties of, i. 515.
Cone, i. 188.
Conic Section, i. 189.
Hyperbola, acute, i. 515.
" ambigenal, i. 515.
" apollonian, i. 515.
" deficient, i. 515.
" equilateral, i. 515.
" infinite, or hyperbolas of the higher kinds, i. 515.
Hyperbolic Conoid, i. 515.
Hyperboloid, i. 515.
Hyperbolic Curve, i. 515.
Hyperbolic Cylindroid, i. 515.
Hyperboloid, i. 515.
To find the solidity of an hyperboloid, or the frustum of an hyperboloid, i. 515.
Conoid, i. 190.
Hyperthyrum, i. 516.
Hypocaustum, i. 516.
Remains of in Britain, i. 516.
Hypodromus, i. 516.
Hypogæum, i. 516.
Hypopodium, i. 516.
Hyposcenium, i. 516.
Hypotrachelium, i. 516.

Ice-House, ii. 1.
Situation of, ii. 1.
Construction of, ii. 1.
Ichnography, ii. 1.
Icosahedron, ii. 1.
Image, ii. 1.
Perspective, ii. 280.
Imagery, ii. 1.
Imbow, ii. 1.
Imbowment, ii. 1.
Impages, ii. 1.

Impetus, ii. 2.
Impluvium, ii. 2.
Impost, ii. 2.
In-band Jamb Stone, ii. 2.
Incertain Wall, ii. 2.
Wall, ii. 522.
Inch, ii. 2.
Inclination, ii. 2.
Inclined Plane, ii. 2.
Mode of determining their inclinations, ii. 2.
Incrustation, ii. 2.
Indefinite, ii. 2.
Indented, ii. 2.
Indian Architecture, ii. 2.
History of, ii. 2.
Origin of Oude and Canouge, ii. 2.
Origin of Delhi, ii. 3.
Description of Lahore, ii. 3.
" of Agra, ii. 3.
" of Indian temples, ii. 3.
" of five different forms of ditto, ii. 3.
" of temples on banks of the Ganges and other rivers, ii. 4.
" of Indian sculptures, ii. 4.
" of sculpture between Balkh and Cabool, ii. 4.
" of ditto at temple of the Sun, near Juggernaut, ii. 4.
Various examples of Indian sculpture, ii. 4.
Sir W. Jones on the affinity between Indian, Egyptian, and African architecture, ii. 5.
Indian and Egyptian mythology compared, ii. 5.
Of the Hindostan edifices, ii. 5.
Detail of Indian architecture, ii. 5.
Description of the city of Agra, ii. 5.
" of Cuttek, ii. 5.
" of Indian pyramids, ii. 6.
" of excavations, ii. 6.
" Elephanta, ii. 6.
" of Canara, in the Island of Salsette, ii. 6.
List of temples described by Sir C. Mallet, ii. 6.
Description of Kylas or Paradise, ii. 7.
Dimension of the Kylas, ii. 8.
Descriptions of the temple of Seringham, ii. 10.
" Ahmed Abad, in Guzerat, ii. 10.
" Jumma Mesgid, ii. 10.
" Baswara, or Bezora, ii. 10.
" Benares, in the city of Casi, ii. 10.
" Mattra, ii. 10.
" Juggernaut, ii. 10.
" temples of Godama, i. 11.
" Ummapoora, ii. 11.
" the present practice of Hindoo architecture, ii. 11.
" building their houses, ii. 11.
Indian Ink, ii. 12.
Indian Red, ii. 12.
Indian Yellow, ii. 12.
Indian Rubber, ii. 12.
Preparation and use of, ii. 12.
Indurating, ii. 12.
Infirmary, ii. 12.
Inlaying, ii. 12.
Marquetry, ii. 117.
Mosaic, ii. 220.
Veneer, ii. 518.
Inn, ii. 12.
Inner Plate, ii. 12.
Inner Square, ii. 12.
Inscribed, ii. 12.
Inscribed Figure, ii. 12.
Inserted Column, ii. 12.
Instruments, *Mathematical*, ii. 12.
Descriptions of, ii. 12.
Uses of the proportional compasses, ii. 13.
" of the sector, ii. 16.
" of Gunter's lines, ii. 17.
Insular, or Insulated Buildings, ii. 17.
Insulated Column, or Detached Column, ii. 17.
Intaglios, ii. 17.
Intavolata, ii. 17.
Cymatium, i. 225.
Intercepted Axis, ii. 17.
Intercolumn, ii. 17.
Intercolumniation, ii. 17.
Colonnade, i. 177.
Interdentils, ii. 17.
Interduces, ii. 17.
Inter-Ties, ii. 18.
Inter-Fenestration, ii. 18.
Inter-Joist, ii. 18.
Interior Angle, ii. 18.
Interior and Opposite Angles, ii. 18.
Interior Polygon, ii. 18.
Polygon, ii. 319.
Intermitting, ii. 18.
Inter Modillion, ii. 18.
Internal Angle, ii. 18.
Interior Angle, ii. 18.
Internal Angle of a Solid, ii. 18.
Interpensivæ, ii. 18.
Inter Pilaster, ii. 18.
Inter Quarter, ii. 18.
Inter Ties, ii. 18.
Intrados, ii. 18.
Invention, ii. 18.
Inverted Arches, ii. 18.
Foundation, i. 429.
Involute, ii. 18.
Evolute, i. 392.
Inward Angle, ii. 18.
Internal Angle of a Solid, ii. 18.
Ion, ii. 18.
Ionic Order, ii. 18.
Origin of, ii. 18.
Capital, ii. 19.
Angular capital, ii. 19.
Base, ii. 19.
Flutings of shaft, ii. 20.
Entablature, ii. 20.
Grecian examples, ii. 20.
Roman varieties, ii. 21.
Modern examples, ii. 21.
Table of proportions, ii. 22.
Iron, ii. 22.
Nature and history of, ii. 22.
Smelting, ii. 22.
Blast-furnace, ii. 22.
Hot blast, ii. 23.
Comparative strength of hot and cold blast-iron, ii. 23.
Uses of cast-iron, ii. 23.
Wrought-iron, ii. 23.
Properties of, ii. 24.

Table of specific gravity and strength of wrought-iron, ii. 24.
To preserve iron from rust, ii 24.
Annealing, ii. 25.
Corrugated iron, ii. 25.
Iron founderies, ii. 25.
Iron Bridge, ii. 25.
Of the inventors of iron bridges, ii. 25.
Bridge, i. 58.
Iron bridge over Severn, at Colebrook Dale, ii. 25.
Do. do. at Buildwas, ii. 26.
Iron bridge over the Wear, near Sunderland, ii. 26.
Bridge over the Witham, at Boston, ii. 27.
Two bridges over the Avon, at Bristol, ii. 27.
Bridge in Sutherland by Telford, ii. 27.
Suspension Bridge, ii. 481.
Bridge over Menai Straits, by Telford, ii. 28.
Report of Mr. Telford, ii. 28.
Bridge over Trent, ii. 30.
Specification of works for same, ii. 30.
Southwark Bridge, ii. 32.
Pont des Arts, Paris, ii. 32.
Combination of wrought and cast-iron for railway bridges, ii. 33.
Tie bridge over canal, Camden Town, ii. 33.
Railway bridge over the Lea, ii. 34.
Bridge over Dee, near Chester, ii. 34.
Straight girder bridge, ii. 35.
Of the new mode of construction introduced by Mr. Stephenson, ii. 35.
Of the Britannia and Conway bridges, ii. 35.
Iron Chain, ii. 39.
Iron Girder, ii. 39.
Iron King and Queen Posts, ii. 39.
Iron Stone, ii. 39.
Iron Wood, ii. 39.
Irregular, ii. 39.
Irregular Bodies, ii. 39.
" Figure, ii. 39.
Irrigation, ii. 39.
Isagon, ii. 39.
Isiac Table, ii. 39.
History of, ii. 39.
Isle, ii. 40.
Aisle, i. 2.
Isodomum, ii. 40.
Walls, ii. 522.
Isosceles Triangle, ii. 40.
Isothermal Lines, ii. 40.
Isthmian Games, ii. 40.
Olympian Games, ii. 243.
Circus, i. 164.
Isis, ii. 40.
Egyptian Architecture, i. 351.
Italian Architecture, ii. 40.
Date and origin, ii. 40.
Description of the palace of the Doge of Venice, ii. 40.
Building of Cathedral at Florence, ii. 40.
Description of this style, ii. 40.
Of lighting apertures, ii. 40.
Of fenestration and columniation, ii. 40.
Of the walls, ii. 41.
Of the cornice, or cornicione, ii. 41.
Of the pediment, ii. 41.
Table of names, &c., of Italian architects, together with the buildings which they erected, ii. 42.
Division of Italian architecture into three kinds, ii. 42.
Of the Florentine style, ii. 42.
Origin of this style, ii. 42.
Description of ditto, ii. 42.
" of Cathedral of St. Maria Del Fiore, ii. 43.
" of the Pitti Palace, ii. 43.
" Palazzo Strozzi, ii. 43.
" Ricardi Palace, ii. 44.
" Church of San Lorenzo, ii. 44.
" " San Spirito, ii. 44.
Of the Roman style, ii. 44.
Description of St. Peter's, ii. 44.
Table of dimensions of St. Peter's, Rome, in comparison with St. Paul's, London, ii. 45.
Mr. Gwilt's table of dimensions of St. Peter's, Rome, in comparison with St. Paul's, London, and St. Mary's, Florence, ii. 46.
Description of Farnese Palace, ii. 46.
Palazzo Giraud, Rome, ii. 46.
Of the Venetian style, ii. 46.
Description of library of St. Mark, ii. 46.
" Procuratie Vecchi, ii. 46.
" Pompeii Palace, ii. 46.
" Palladio's Works, ii. 46.
" Olympic Theatre, at Vicenza, ii. 47.
" the Church of the Redeemer, Venice, ii. 47.
" Church of della Sapienza, ii. 47.
" Palace of Berberini, ii. 47.
Introduction of Italian Architecture into England, ii. 48.
Description of Whitehall, ii. 48.
Works by Inigo Jones, ii. 48.
Of Sir C. Wren, and his buildings, ii. 48.
Description of structures anciently holding the same site as St. Paul's Cathedral, ii. 48.
Description of the present structure, ii. 50.
Of the different plans sent in by Sir C. Wren for this building, ii. 50.
Of its external form, ii. 50.
Of its internal do., ii. 51.
Defects in the plan, ii. 52.
Of the ground plan, ii. 52.
Dimensions of building, ii. 53.
Expense of erection, ii. 53.
Description of St. Stephen's, Walbrook, ii. 53.
" St. Bride's, ii. 53.
" St. Mary le Bow, ii. 53.
" St. Mary's, Woolnoth, ii. 53.
" Somerset House, ii. 53.
Club House, i. 169.
Description of Bridgewater House, ii. 54.
Ivory, ii. 54.

Jack, Lifting Jack, ii. 55.
Jack Arch, ii. 55.
Jack in the Box, ii. 55.
Jack Plane, ii. 55.
Jack Rafter, ii. 55.
Jack Ribs, ii. 55.
Jack Timber, ii. 55.
Jack Wood, ii. 55.
Jambs, ii. 55.
Jamb Lining, ii. 55.
" Posts, ii. 55.
" Stones, ii. 55.
Jantu, ii. 55.
Japanning, ii. 55.
Jerkin Head, ii. 55.
Jet d'Eau, ii. 55.

Fountain, i. 430.
JETTEE, JETTY, or JUTTY, ii. 55
JIB DOOR, ii. 55.
JOGGLE, ii. 55.
JOGGLE PIECE, ii. 55.
JOINER, ii. 55.
JOINERY, ii. 55.
Technical terms applied to the different modes of cutting wood for use, ii. 55
Of grooving, ii. 56.
Rebating, ii. 56.
Mortising, ii. 56.
The tenon, ii. 56.
Preparation of the stuff, ii. 56.
Plane, ii. 299.
Tools used by joiners, ii. 56.
To make a straight edge, ii. 57.
To reduce the rough surface of a body to a plane, ii. 58.
To join any number of planks together so as to form a board of a determinate breadth, the fibres of each running longitudinally to those of any other, ii. 58.
To glue any two boards together forming a given angle, ii. 58.
To form wooden architraves for apertures by gluing longitudinal pieces together, ii. 58.
To form the surface of a cylinder with wood whose fibres are in planes perpendicular to the axis of the cylinder, ii. 58.
To bend a board so as to form the frustum of a cone, or any segmental portion of the frustum of a cone, ii. 59.
Envelope, i. 387.
To bend boards so as to form a spheric suface, ii. 59.
To glue up the shaft of a column, supposing it to be the frustum of a cone, ii. 59.
To glue up the Ionic and Corinthian capitals for carving, ii. 59.
To make a cornice round a cylindric body of the least quantity of wood, when the body is greater than a half cylinder, and when the members will nearly touch a right line applied transversely, ii. 59.
Mouldings, ii. 221.
The section of the horizontal bar being given, to find that of the angle bar, ii. 60.
Of joining boards, ii. 61.
Table of technical terms, ii. 61.
Mouldings, ii. 62.
To scribe one piece of board or stuff to another, ii. 62.
To scribe the edge of a board against any uneven surface, ii. 62.
To rebate a piece of stuff, ii. 62.
To rebate across the grain, ii. 63.
Stairs, ii. 63.
" geometrical, ii. 64.
" dog legged, ii. 63.
Dog-legged Stairs, i. 274.
Bracket Stairs, ii. 63.
Handrailing, i. 487.
Geometrical Stairs, ii. 64.
Doors, ii. 65.
Of hanging doors, ii. 66.
Mouldings of do., ii. 66.
Geometrical descriptions in Joinery, ii. 67.
To find the true bevel for hanging any door, ii. 67.
To find the joint for a pair of folding doors, ii. 67.
To find the bevel on the edge of a door when it is executed on a circular plan, and the door to turn towards the space on the convex side of the circle, ii. 67.
To find the meeting joint of folding doors when the hinges are placed on the concave side of the doors, ii. 67.
Elevation of a pair of folding doors to be shut quite out of the way, in order to open a communication between two rooms, or throw both into one, ii. 67.
To find the joint of a jib door, so that it shall open freely at the hanging side, and the joint to be a plane surface, ii. 67.
Construction of sash-frames and window-shutters, ii. 68.
Customary measures in joiner's work for labour only, ii. 70.
Rates of labour in joiner's work, ii. 71.
English writers on joinery, ii. 74.
The Art of sound building :—
To find the raking arch or mould for the hand-rail to a circular pair of stairs in such manner, that it shall stand perpendicularly over its base or arch of the well-hole, ii. 74.
The arch or mould of the rail being found as above, how to prepare the stuff, of which the rail is to be made, and work the twist thereof, without setting it up in its due position, ii. 75.
How to form the arch or moulds to the handrail of a pair of stairs that sweeps two steps, so as to stand perpendicular over its ground; and manner of squaring same, without setting it up in its position, ii. 75.
The British Carpenter :—
To find the proper kneeling and ramp of rails, ii. 76.
Spiral, ii. 440.
Scroll, ii. 409.
Mr. Price on method of forming raking-mouldings for pediments, ii. 79.
Extract from Mr. Salmon's London Art of Building—
On the formation of rails for winding stairs, ii. 79.
Langley's improvements on ditto, ii. 79.
To describe a twisted rail, ii. 79.
To describe the mould for the twist, ii. 80.
To find the mould of a twisted rail to a circular or elliptical staircase, ii. 80.
To find the curvature or mould of the raking ovolo that shall mitre with the level ovolo, ii. 80.
To find the curvature or mould of the returned moulding, in an open or broken pediment, ii. 81.
Manner of squaring twist-rails, ii. 81.
To find the rail, ii. 81.
To find the width of the rail-mould, ii. 81.
On Mr. William Pain's Works, ii. 82.
Soffit, ii. 434.
On inventions by Mr. Nicholson, ii. 83.
Further explanation of Plates, ii. 84.
Method of hinging folding-doors, ii. 85.
To make a door swing either way, supposing the jamb formed alike on either side, ii. 85.
To make the joints correspond to a rebate on the opposite jamb or lintel, ii. 85.
The method of concealing the revolving joint of doors and shutters, ii. 85.
JOINT, ii. 85.
JOINTER, *in Joinery*, ii. 85.
JOINTER, *in Bricklaying*, ii. 85.
JOINTING RULE, ii. 85.

JOISTS, ii. 85.
JONES, INIGO, ii. 85.
JUFFERS, ii. 86.
JUMP, ii. 86.
JUMPER, ii. 86.

KAABA, ii. 86.
Caaba, i. 73.
KALEIDOSCOPE, ii. 86.
KAOLIN, ii. 86.
KEEP TOWER, ii. 86.
Castle, i. 110.
KEEPING, ii. 86.
KENILWORTH CASTLE, ii. 86.
KERF, ii. 86.
KEY, ii. 86.
KEY, or COTTAR, ii. 86.
KEY, or QUAY, ii. 86.
KEY, ii. 86.
Lock, ii. 108.
KEY OF A FLOOR, ii. 86.
KEYED DADO, ii. 86.
KEY-HOLE, ii. 86.
KEY-PILE, ii. 86.
KEYS, ii. 86.
KEYS, *in Joinery*, ii. 86.
Dado, i. 226.
KEY-STONE, ii. 87.
KILDERKIN, ii. 87.
KILN, ii. 87.
KILN, *Brick*, ii. 87.
Brick, i. 44.
KILN, *Hop*, ii. 87.
KILN, *Lime*, ii. 87.
On manufacture of lime, ii. 87.
" construction of kiln, ii. 87.
" the furnace of do., ii. 87.
" sod kilns, ii. 87.
" draw kilns, ii. 88.
Count Rumford on do., ii. 88.
Of flame-kilns, ii. 88.
Mr. Rawson's method of constructing lime-kilns, ii. 89.
Mr. Charles Heathorn's patent, ii. 89.
On use of peat for burning lime, ii. 89.
KILOMETRE, ii. 90.
KING-POST, or CROWN-POST, ii. 90.
Crown Post, i. 215.
KIOSK, ii. 90.
KIRB-PLATE, ii. 90.
Curb Plate, i. 217.
KIRB-ROOF, ii. 90.
Curb-Roof, i. 217.
KITCHEN, ii. 90.
Utensils for do., ii. 90.
KNEE, ii. 90.
KNEE, *in Hand-railing*, ii. 90.
KNIFE, *Drawing*, ii. 90.
Drawing-Knife, i. 306.
KNOTTING, ii. 90.
KNUCKLE, ii. 90.
Hinging, i. 495.
KYANIZING, ii. 90.
Description of, ii. 90.

LABEL, ii. 90.
LABOUR, ii. 90.
LABRUM, ii. 91.
LABURNUM, ii. 91.
LABYRINTH, ii. 91.
Description of that of Crete, ii. 91
Do. do. of Egypt, ii. 91.
Labyrinth fret, ii. 92.
LACHRYMATORY, ii. 92.
LACONICUM, ii. 92.
LACUNARIS, LACUNARIA, or LACUNARS, ii. 92.
Example of in Temple of Minerva at Athens, ii. 92.
" " Theseus, Athens, ii. 92.
" " Pandrosus, Athens, ii. 92.
" " Vesta, Rome, ii. 92.
LADDER, ii. 92.
LADY-CHAPEL, ii. 92.
LANCET ARCH, ii. 92.
LANCET WINDOW, ii. 92.
LANDING, ii. 93.
LANTERN, ii. 93.
LAP, ii. 93.
LARDER, or SAFE, ii. 93.
Construction of, ii. 93.
LARMIER, ii. 93.
Corona, i. 203.
LATCH, ii. 93.
LATH, ii. 93.
Dimensions of, ii. 93.
Directions for lathing for plastering, ii. 93.
Manufacture of laths, ii. 93.
LATH BRICKS, ii. 94.
LATHE, ii. 94.
LATTICE, ii. 94.
LATTICE WINDOWS, ii. 94.
LAUNDRY, ii. 94.
Utensils for, ii. 94.
LAVATORY, ii. 94.
LAVER, ii. 94.
LAWN, ii. 94.
Situation and arrangement of, ii. 94.
LAYER, ii. 95.
Course, i. 210.
LAZARETTO, or LAZAR HOUSE, ii. 95.
Origin and use of, ii. 95.
Description and examples of, ii. 95.
LEAD, ii. 96.
Properties of, ii. 96.
Use of, ii. 96.
Plumbery, ii. 312.
LEAN-TO, i. 96.
LEAVER, ii. 96.
LEVER, ii. 97.
Leaver Boards, ii. 96.
Lever Boards, ii. 101.
LEAVES, ii. 96.
Ornament, ii. 245.
LEDGE, ii. 96.
LEDGEMENT, ii. 96.
LEDGERS, ii. 96.
LEGAL COLUMN, ii. 96.
Column, i. 179.
LEGS, ii. 96.
LEGS, *of an Hyperbola*, ii. 96.
LENGTH, ii. 96.
LENGTHENING, ii. 96.
Scarfing, ii. 408.
LESBIUM MARMOR, ii. 96.
LEVEL, ii. 96.
LEVEL, *Carpenter's*, ii. 96.

Description of, ii. 96.
Use of, ii. 96.
To adjust the level, ii. 96.
Of the spirit or air level, ii. 97.
Levelling, ii. 97.
Lever, or Leaver, ii. 97.
Various kinds of levers, and their particular properties, ii. 97.
Principles and laws of motion, ii. 97.
Composition and resolution of forces, ii. 98.
If any body, A, be moved by any impulse which would cause it to describe the right-line A B, uniformly in a given time, and if the same body A, be moved by another impulse which would cause it to describe the right-line A D, uniformly in an equal time; these two impulses acting at the same instant, would carry the body through the diagonal A C of a parallelogram A B C D, ii. 98.
Given the tracts, intensities, and tendencies of two forces making any angle with each other, to find a single force equivalent to them, ii. 98.
To resolve any force into two others in any given directions which shall act against any point of the line of direction of the given force, ii. 98.
If any two forces keep a third in equilibrio, the direction of the third has the same point of concourse, and is in the same plane with the other two, and all the three forces are, to each other, as the sides and diagonal of a parallelogram formed on their lines of direction, ii. 98.
The lines of direction of three forces keeping each other in equilibrio, and the intensity and tendency of one of them being given, to find the intensity and tendency of the other two, ii. 99.
Given, the directions of four forces in the same plane, keeping a solid in equilibrio, and one of the intensities, to find the intensities of the other three, ii. 99.
Given, the direction of five forces in one plane, keeping a solid in equilibrio, and the intensities and tendencies of two of them, to find the intensities and tendencies of the rest, ii. 99.
If there be two straight lines, A B, B C, making any angle, A B C, with each other, and if two forces equal and opposite in the directions A X, C Y, in the same straight line, be applied, and three others in the directions A W, B Z, C J, then if the whole be in equilibrio, the directions Z B, A W, C J, will have the same point of concourse, or otherwise they will be parallel, ii. 99.
If three forces acting against the same point be in equilibrio with each other, and if any point F, taken in the line of direction of any of the forces, the other two forces are to each other, reciprocally, as the distance of their lines of direction from that point, ii. 100.
If a solid A B C, be supported by three forces in the lines of direction Z B, A W, C J, these three lines will have the same point of concourse, or be parallel to each other, ii. 100.
If a solid be in equilibrio by three forces, and if any point be taken in the line of direction of any one of them; the products of each of the other two by the distance of their respective lines of direction from that point will be equal, ii. 100.
Lever Boards, ii. 101.
Library, ii. 101.
Origin of, ii. 101.
Of early libraries, ii. 101.
Libraries of London, ii. 101.
Table of different sizes of paper, ii. 101.
Lighthouse, ii. 102.
Use of, ii. 102.
Form of, ii. 102.
The Pharos of Alexandria, ii. 102.
Eddystone Lighthouse, i. 328.
Description of Bell-rock lighthouse, ii. 102.
Table showing the relative dimensions of Eddystone and Bell-rock lighthouses, ii. 102.
Construction of, ii. 102.
Watt's invention of the jib and counterpoise cranes, ii. 103.
Of the Skerrymore Rock lighthouse, ii. 104.
Of the screw-pile, ii. 104.
Mode of constructing Point of Air lighthouse, ii. 105.
Mr. C. Fox's method of forming foundations for piers or bridges, ii. 105.
On Mr. Bush's light of all nations, ii. 106.
On iron lighthouses, ii. 106.
On the illumination of lighthouses, ii. 106.
Examples of ditto, ii. 107.
Like Arcs, ii. 107.
Like Figures, ii. 107.
Like Solids, ii. 107.
Limestone, ii. 107.
Cement, i. 128.
Lime Kiln, ii. 107.
Kiln, ii. 87.
Lime, *quick*, ii. 107.
Line, ii. 107.
" Equinoctial, ii. 107.
" Geometrical, ii. 107.
" Horary, or Hour Lines, ii. 108.
" Horizontal, ii. 108.
" Vertical, ii. 108.
" Visual, ii. 108.
" of Direction, ii. 108.
" of Light, ii. 108.
" of Measures, ii. 108.
" of Shade, ii. 108.
" of Station, ii. 108.
Lines, *Division or Gradation of*, ii. 108.
" of the Proportional Compass, ii. 108.
" of the Plain Scale, ii. 108.
" of the Sector, ii. 108.
Linear Perspective, ii. 108.
Lining, ii. 108.
" of a Wall, ii. 108.
Lining-out Stuff, ii. 108.
Linings of Boxings, ii, 108.
" of a Door, ii. 108.
" of a Sash Frame, ii. 108.
Lintel, ii. 108.
Lintels, or Fir-in-Bond, ii. 108.
List, or Listels, ii. 108.
Fillet, i. 414.
Listing, ii. 108.
Lobby, ii. 108.
Lock, ii. 108.
Description of, ii. 108.
Lock, or Weir, ii. 109
" Paddles, ii. 109.
" Sills, ii. 109.
" Weirs, or Paddle Weirs, ii. 109.
Locker, ii. 109.

Locus, ii. 109.
Loft, ii. 109.
Log Houses, ii. 109.
Logarithms, ii. 109.
Logeum, ii. 109.
Loggia, ii. 109.
Logistic Spiral, or Proportional Spiral, ii. 109.
Lombardic Architecture, ii. 109.
Its origin, ii. 109.
Its progress, ii. 109.
A subdivision of Romanesque, ii. 109.
Its characteristics, ii. 109.
Form of arch, ii. 109.
External and internal arcades, ii. 110.
Do. under gables, ii. 110.
Corbel-tables, ii. 110.
Pilaster strips, ii. 110.
Windows, ii. 110.
Doorways, ii. 110.
Walls, ii. 110.
Porch, ii. 110.
Internal arrangement, ii. 110.
Plan, ii. 110.
Admixture with Byzantine and Roman, ii. 110.
Domes and apsides, ii. 110.
Form and treatment of arches, ii. 111.
Do. pillars, ii. 111.
Do. bases, shafts, and capitals, ii. 111.
Do. proportions of, ii. 111.
Campaniles, ii. 111.
Descriptions of Churches, ii. 112.
" San Michele, Pavia, ii. 112.
" San Thomaso, ii. 112.
" Ambrozzi, Milan, ii. 112.
" S. Geron's church, ii. 112.
" Cathedral at Pisa, ii. 112.
" Duomo, Modena, ii. 112.
" S. Zenone, Verona, ii. 1 3.
" San Michele, Lucca, ii. .13.
Saxon Architecture, ii. 400.
Norman " , ii. 234.
Romanesque " , ii. 374.
Longimetry, ii. 113.
Loop Holes, ii. 113.
Lorme, Philibert De, ii. 113.
Louvre, ii. 113.
Lozenge, ii. 113.
Lozenge Moulding, ii. 113.
Luculleum Marmor, ii. 113.
Luffer Boarding, ii. 113.
Lune, or Lunula, ii. 113.
Lunette, ii. 113.
Luthern, ii. 113.
Lych Gate, or Lich Gate, ii. 113.
Lying Panels, ii. 113.

Machicolations, ii. 114.
Machine, ii. 114.
Definition of, ii. 114.
Various classes of, ii. 114.
Maderno, Charles, ii. 114.
Magazine, Powder, ii. 114.
Description of, ii. 115.
Mahogany, ii. 115.
Spanish Mahogany, ii. 115.
Honduras Mahogany, ii. 115.
Table of strength, ii. 115.
Main Couples, ii. 115.
Couples, i. 210.
Mallet, ii. 115.
Mansard Roof, ii. 115.
Curb Roof, i. 217.
Mansart, Francis, ii. 115.
Life of, ii. 116.
Mansion, ii, 116.
Mantle Tree, or Mantel Tree, ii. 116.
Marble, ii. 116.
Marbles of one colour, ii. 116.
" of two colours, ii. 116.
" of many colours, ii. 116.
" polishing of, ii. 117.
" sawing of, ii. 117.
Margin, ii. 117.
Marquetry, ii. 117.
Masonry, ii. 117.
Description of stones, ii. 117.
Cement, i. 128.
Mortar, ii. 214.
On foundations, ii. 118.
Foundation, i. 429.
Concrete, i. 186.
On construction of walls, ii. 118.
" rubble work, ii. 118.
" ashlar facing, ii. 118.
" bond stones, ii. 119.
" arches, ii. 119.
Definition of terms used in connection with masonry, ii. 119.
Different kinds of do., ii. 119.
Of a simple vault, ii. 120.
Groin, i. 477.
To construct a semi-cylindroidic arch cutting a straight wall, with its axis oblique to the surface of the wall, but parallel to the horizon, ii. 120.
To find any level which the joints on the face of the arch makes with that on the intrados, ii. 120.
To construct a cylindro-cylindric arch, or a cylindric arch in a cylindric wall, the axis of the aperture being at right angles to the axis of the cylindric wall, ii. 121.
To find the curves of the ends of the beds upon the face of the arch, ii. 121.
To form an arch stone, ii. 121.
Materials, ii. 121.
Of materials used by the Greeks and Romans, ii. 121.
Their time of felling, and mode of seasoning timber ii. 121.
Different kinds of stones used by them, ii. 121.
Do. do. tiles and bricks, ii. 121.
Mode of manufacturing do., ii. 121.
Do. lime for plastering walls, ii. 122.
Metals used by ditto, ii. 122.
Time of felling trees in England, ii. 122
Choice of timber for building, ii. 122.
Mode of seasoning oak, ii. 122.
" ash, ii. 122.
" elm, ii. 122.
" beech, ii. 122.
" poplar, ii. 122.
" birch, ii. 122.
" chesnut, ii. 122.
" walnut, ii. 123.
" mahogany, ii. 123
Mahogany, ii. 115.

Mode of seasoning fir, ii. 123.
Evelyn on timber, ii. 123.
Seasoning of elm, ii. 123.
Charring of wood, ii. 123.
To prevent chops and clefts in wood during the process of seasoning, ii. 124.
Different modes of preserving timber, ii. 124.
To judge of the different qualities of timber, ii. 124.
Causes of the decay of wood, ii. 124.
On the dry-rot, ii. 125.
Dry-rot, i. 308.
On charring of wood, ii. 125.
Table of the properties of different kinds of timber, ii. 125.
Of different kinds of stone, ii. 126.
Slate, ii. 431.
Of bricks, ii. 126.
Brick, i. 44.
Of tiles, ii. 126.
Tile, ii. 489.
Of sand, ii. 127.
Cement, i. 128.
Of metals, ii. 127.
Of glass, ii. 127.
Glass, i. 447.
MATHEMATICS, ii. 127.
Definition of, ii. 127.
Derivation of term, ii. 127.
Treatise on, ii. 127.
List of mathematicians, ii. 128.
MATHEMATICAL INSTRUMENTS, ii. 130.
Instruments, ii. 12.
MAUSOLEUM, ii. 130.
Description of tomb of Mausolus, ii. 130.
" of mausoleum at Babylon, ii. 130.
" " of Augustus and Hadrian, Rome, ii. 130.
Mausolea in England, ii. 130.
MEASURE, ii. 130.
MEASURE OF AN ANGLE, ii. 130.
Angle, i. 6.
MEASURE OF A FIGURE, or PLANE SURFACE, ii. 130.
" OF FORCE, ii. 130.
" OF A LINE, ii. 131.
MEASURES, LINE OF, ii. 131.
Line, ii. 107.
MEASURE OF THE MASS, or QUANTITY OF MATTER, ii. 131.
Weight, ii. 523.
MEASURE OF A NUMBER, ii. 131.
" SOLID, ii. 131.
Cube, i. 216.
Mensuration, ii. 164.
MEASURE OF VELOCITY, ii. 131.
" UNIVERSAL AND PERPETUAL, ii. 131.
" *in a Legal and Popular Sense*, ii. 131.
Ancient laws respecting, ii. 131.
Introduction of imperial system, ii. 131.
The rationale of imperial system, ii. 132.
The standard yard, ii. 132.
" pound, ii. 132.
" gallon, ii. 132.
" for heaped measure, ii. 132.
Stricken measure, ii. 132.
Extracts from Bill for ascertaining and establishing uniformity of weights and measures, ii. 132.
Table of the several standard measures, English and Foreign, ii. 133.
Tables of different measures, according to various authorities, reduced to English measurement, ii. 134.
Scripture long measure, ii. 134.
Jewish long or itinerary measure, ii. 134.
Grecian long measure, ii. 134.
Roman long measure, ii. 135.
Other ancient long measures, ii. 135.
Scottish do., ii. 135.
French do., before the first Revolution, ii. 135.
Do. do. according to the present system, ii. 135.
Proportions of several long measures to each other, ii. 136.
Proportions of the long measures of several nations to the English foot, ii. 136.
Modern long measures of several countries compared with English feet, ii. 136.
A comparison of the foot and other measures of length in different countries, ii. 138.
A comparison of the itinerary measures of different countries, ii. 139.
Ancient Greek superficial measures, ii. 139.
Ancient Roman land-measures, ii. 139.
English square measures, ii. 140.
Measures used by different artificers, ii. 140.
French square measures before the first Revolution, ii. 140.
Do. do. according to the present system, ii. 140.
Contents of a square foot of different countries, ii. 140.
Cubical measures, or measures of capacity for liquids, of various countries, ii. 140.
Measure of capacity for things dry, as used in different countries, ii. 141.
MEASURING, or MENSURATION, ii. 142.
" OF LINES, ii. 142.
" SUPERFICIES, ii. 142.
" OF SOLIDS, ii. 142.
Arc, i. 11.
Circle, i. 162.
Mensuration, ii. 164.
MECHANICS, ii. 143.
Force, i. 420.
Motion, ii. 221.
Power, ii. 323.
Of practical and rational mechanics, ii. 143.
Mechanical knowledge of the ancients, ii. 143.
MECHANICAL CARPENTRY, ii. 143.
Definition of, ii. 143.
Constructive Carpentry, i. 193.
Roof, ii. 374.
Carpentry, i. 80.
Curb Roof, i. 217.
To find the comparative strength of timber, ii. 144.
Given, the length, breadth, and depth, of a piece of timber, to find the depth of another piece whose length and breadth are given, so that it shall bear the same weight as the first piece, or any number of times more, ii. 144.
Given, the length, breadth, and depth, of a piece of timber, to find the breadth of another piece whose length and depth are given, so that the last piece shall have the same weight as the first, or any number of times more, ii. 145.
If a piece of timber sustain a force placed unequally between the extremes on which it is supported, the strength in the middle will be to the strength in that part of the timber so divided, as one divided by the square of half the length is to one divided by the

rectangle of the two unequal segments, that is, in the reciprocal ratio of their products, ii. 145.
Having the length and weight of a beam that can just support a given weight in the middle; to find the length of another beam of the same scantling, that shall just break with its own weight, ii. 146.
Having the weight of a beam that can just support a given weight in the middle; to find the depth of another beam similar to the former, so that it shall just support its own weight, ii. 146.
The weight and length of a piece of timber being given, and the additional weight that will break it; to find the length of a piece of timber similar to the former, so that this last piece of timber shall be the strongest possible, ii. 147.
Belidor's Experiments, ii. 148.
M. de Buffon's do., ii. 149.
M. du Hamel, do., ii. 150.
Further experiments, ii. 150.
Of the absolute strength of timber, ii. 150.
Table showing the strength of a square inch in different kinds of timber, ii. 150.
Practical observations, ii. 150.
To cut the strongest beam possible out of a round tree, whose section is a given circle, ii. 151.
To support a piece of timber by means of two props resting on the gronnd, so that it shall have no tendency to go to either side, ii. 151.
To ascertain the proportions between the weight of the piece of timber, and the compression of the props, ii. 151.
If a heavy body, A, B, C, D, be supported by two oblique strings, D, E, and C F, in a vertical plane, a straight line drawn through the intersection will pass through the centre of gravity of the body, ii. 151.
Given the position in which a body should be placed, and the position of a plane supporting the body at one end; to find the position of another plane to support it at another given point, and to find the pressure on the planes, the weight of the body being given, ii. 151.
Lever, ii. 97.
Actual experiments on composition of forces, ii. 152.
To distinguish ties from struts, ii. 153.
Strains acting on various points of a frame of carpentry, ii. 154.
Building up and scarfing of beams, ii. 158.
Of joints, ii. 160.
Of iron straps, ii. 161.
Of circular and polygonal roofs, ii. 162.
Of trusses and centres, ii. 162.
Stone Bridge, ii. 462.
MECHANICAL POWERS, ii. 164.
The proportion the power and weight ought to have to each other, ii. 164.
The proportion of the power and weight to each other in a given machine, that it may produce the greatest effect possible in a given time, ii. 164.
Lever, ii. 97.
Plane, (*inclined*), ii. 302.
Pulley, ii. 345.
Wedge, ii. 522.
Wheel, ii. 525.
MEDALLION, ii. 164.
MEDIÆVAL ARCHITECTURE, ii. 164.
MEDIANÆ, ii. 164.
MEMBER, ii. 164.
MENSURATION, ii. 164.
Origin of, ii. 164.
Progress of, ii. 165.
Spiral, ii. 440.
Mensuration of lines, ii. 166.
Any two sides of a right-angled triangle being given, to find the third, ii. 166.
To find the length of a cylindrical helix, ii. 167.
The chord and versed sine of an arc of a circle being given, to find the diameter, ii. 167.
In the segment of a circle are given the chord and its distance from the centre, to find the radius of the circle, ii. 167.
The radius of a circle being given, and the chord of a segment of that circle, to find the versed sine of the lesser segment, ii. 168.
Given the distance between the two parallel sides of a trapezoid, and the breadth of the lesser end; to find the breadth of the greater end, so that the sides may tend to a point at any given distance, ii. 168.
To find any point in the arc of the segment of a circle, at the extremity of an ordinate, the radius of the circle, the chord of the arc, and the distance of the ordinate from the middle of the chord, being given, ii. 169.
Given the chord of a very large segment of a circle, the radius of the circle, to find any number of points in the arc, and thence to describe it, ii. 169.
Geometry, i. 445.
In a parabola having two abscissas and an ordinate to one of them, to find the ordinate of the other, ii. 169.
To find any point in the curve of a parabola by means of an abscissal parallel, or transverse ordinate; the height or abscissa, the ordinate, and the distance of the transverse ordinate from the abscissa, being given, ii. 170.
Given the abscissa and ordinate of a parabola, to find any number of equidistant diameters or abscissal parallels, and consequently points in the curve at the extremities, ii. 170.
Synopsis of the principal rules in Mensuration, ii. 170.
The rectification, or development of curves, ii. 170.
Areas of plain surfaces, ii. 171.
" curved do., ii. 172.
Solidities of bodies, ii. 172.
Rectification of curves, ii. 173.
Areas of plane figures, ii. 175.
" curved surfaces, ii. 176.
Notes on the solidities of bodies, ii. 178.
Of measuring curvilinear planes and solids by approximation, ii. 178.
Observations on averaging surfaces bounded on one or two opposite sides by a curve, ii. 179.
Mensuration of artificers' work, ii. 180.
Bricklayers' work, ii. 180.
To measure the vacuity of a window, ii. 180.
" any angle chimney standing equally distant each way from the angle of the room, ii. 181.
To measure an angle chimney when the plane of its breast intersects the two sides of the room unequally distant from the angle, ii. 181.
To measure an angle chimney when the plane of the breast projects out from each wall, and unequally distant from the angle of the room, ii. 181.
To find the area of an arched aperture, ii. 181

To find the area of a wall, or of the foundation of a building placed upon a curved surface, supposing it to be built upon uneven ground, ii. 181.
Table showing the number of rods contained on the superficies or face of the wall or building, from ½ a brick to 5 bricks in thickness, ii. 183.
Table showing how many bricks are sufficient to build a piece of brickwork containing from 1 to 90,000 superficial feet, and from ½ a brick to 2½ bricks in thickness, ii. 183.
Table showing number of rods contained in any number of superficial feet, from 1 to 10,000, and from ½ a brick to 2½ bricks thick, ii. 184.
Table showing value of reduced brickwork, per rod, ii. 184.
Table showing value of brickwork reduced to 1½ brick thick, ii. 184.
Table showing what number of plain or pantiles will cover any area from 1 to 10,000 feet, ii. 185.
A general explanation of the tables and their construction, ii. 185.
Table of size and weight of various articles, ii. 189.
Quantities, ii. 189.
Calculation of labour, ii. 189.
Digger, ii. 189.
Concrete, ii. 189.
Paving, ii. 189.
Tiling, ii. 190.
Masons' work, ii. 190.
Weight of stone, ii. 190.
Valuation of labour, ii. 190.
Carpenters' work, ii. 191.
To measure the centering of a cylindrical vault, ii. 191.
To measure naked floors, whether for materials or workmanship, ii. 192.
To measure roofing or partitions, whether for materials or workmanship, ii. 192.
Valuation of Carpenters' and Joiners' work, ii. 192.
Weight of timber, ii. 193.
Joiners' Work, ii. 193.
Painters' do., ii. 193.
Plasterers' do., ii. 193.
Valuation of do., ii. 193.
Glaziers' do., ii. 193.
Plumbers' do., ii. 194.
Paviors' do., ii. 194.
Slaters' do., ii. 194.
Mensuration of timber, ii. 195.
To find the area or superficial feet in a board or plank, ii. 195.
To find the solid content of squared or four-sided timber, ii. 195.
To find the solidity of round or unsquared timber, ii. 195.
Table for finding content of trees, according to common method of measuring timber, ii. 196.
To find where a piece of round tapering timber must be cut, so that the two parts measured separately, according to the common method of measuring, shall produce a greater solidity than when cut in any other part, and greater than the whole, ii. 197.
To find where a tree should be cut, so that the part next the greater end may measure to the most possible advantage, ii. 197.
To cut a tree so that the part next the greater end may measure by the common method to exactly the same quantity as the whole measures to. ii. 197.
Table of the areas of the segments of a circle whose diameter is unity, and supposed to be divided into 1,000 equal parts, ii. 198.
Meridian, *in Astronomy*, ii. 199.
Meridian, *in Geography*, ii. 199.
Meridian, *first*, ii. 200.
Meridian Line, ii. 200.
Merlon, ii. 200.
Meros, ii. 200.
Mesaulæ, ii. 200.
House, i. 503.
Meta, ii. 200.
Metagenas, ii. 200.
Metals, ii. 200.
Materials, ii. 121.
Iron, ii. 22.
Metatome, ii. 200.
Metezau Clement, ii. 200.
Metoche, ii. 200.
Metope, or Metopa, ii. 201.
Vitruvius on, ii. 201.
Dimensions of various examples, ii. 201.
Mexican Architecture, ii. 201.
Babylonian Architecture, i. 19.
Description of the Teocallis, ii. 201.
Description of pyramid of Cholula, ii. 201.
" " Papantla, ii. 201.
" of ruins known as Casa Grande, ii. 201.
" of palace of Mitla, ii. 201.
" of two pyramids in Valley of Mexico, ii. 202
" of Montezuma's bath, ii. 202.
" of pyramids near the village of Huexotla, ii. 202.
" of pyramids of San Juan di Teotihuacan, ii. 202.
Mezanine, or Mezzanine, ii. 203.
Apartment, i. 8.
Mezzo Relievo, ii. 203.
Basso Relievo, i. 31.
Middle Post, ii. 203.
Crown Post, i. 215.
Middle Quarters of Columns, ii. 203.
Mile, ii. 203.
Measure, ii. 133.
Variation of length of a mile in different countries, ii. 203.
Table of length of miles, leagues, &c., ancient and modern, in English yards, ii. 203.
Military Architecture, ii. 203.
Architecture, i. 14.
Millstone Grit, ii. 203.
Milk-House, or Room, ii. 203.
Dairy, i. 226.
Minaret, or Minneret, ii. 203.
Minion, ii. 203.
Cement, i. 128.
Mortar, ii. 214.
Minotaur, or Minotaurus, ii. 238.
Minster, ii. 203.
Minstrel Gallery, ii. 203.
Minute, ii. 204.
Miserere, ii. 204.
Mitchels, ii. 204.
Mitre, or Mitra, ii. 204.
Mitre, *in Joinery*, ii. 204.
Mitre Box, ii. 204.
Mixed Angle, ii. 204.

Mixed Figure, ii. 204.
Moat, ii. 204.
Model, ii. 204.
Model, *in Painting and Sculpture*, ii. 204.
Modillions, ii. 204.
Description of, ii. 204.
Examples of, ii. 204.
General disposition of, ii. 204.
Dimensions of, ii. 205.
Modular Proportion, ii. 205.
Modulation, ii. 205.
Module, ii. 205.
Different mode of choosing, ii. 205.
Column, i. 179.
Moilon, ii. 205.
Moineau, ii. 205.
Molding, ii. 205.
Moulding, ii. 221.
Mole, ii. 205.
Moment, or Momentum, ii. 205.
Treatise on, ii. 205.
Force, i. 420.
Monastery, ii. 205.
Dissolution of religious houses in England, ii. 206.
Revenues of do., appropriated to the use of the crown, ii. 206.
Number of monasteries, &c., suppressed in England, ii. 206.
Yearly revenue of same at time of dissolution, ii. 206.
Number of inmates of religious houses, ii. 206.
Foundation of bishoprics, ii. 206.
Foundation of several deaneries and chapters, ii. 206.
Foundation of colleges and professorships, ii. 207.
Monkey, ii. 207.
Monogram, ii. 207.
Monolith, ii. 207.
Celtic Architecture, i. 124.
Monopteron, ii. 207.
Monotriglyph. ii. 207.
Monstrance, ii. 207.
Monument, ii. 207.
Of early monuments, ii. 207.
Monument of Lysicrates, ii. 207.
Description of, ii. 207.
Monument, The, ii. 208.
Moorish, Moresque, Arabian, or Saracenic Architecture, ii. 208.
History of, ii. 208.
On the merits of this style, ii. 209.
Of the characteristics of the style, ii. 209.
Of the forms of arches and their treatment, ii. 209.
Of columns, ii. 210.
Of corbelling, ii. 210.
Of various methods of decoration, arabesques, inscriptions, trellis-work, mosaics, &c., ii. 210.
Of the exteriors of buildings, ii. 211.
Mosque, ii. 221.
Division of the style into three periods, ii. 211.
Description of the Mosque of Cordova, ii. 212.
" of the Alhambra, ii. 212.
" of a house at Seville, ii. 314.
Caaba, i. 73.
Moor Stone, ii. 214.
Description of, ii. 214.
Mode of obtaining, ii. 214.
Moot Hall, Moot House, ii. 214.
Moresk, or Moresque, ii. 214.
Mortar, ii. 214.
Mortar, *Hydraulic*, ii. 218.
Composition and properties of, ii. 214.
On ancient mortar, ii. 214.
" lime, ii. 214.
" sand, ii. 215.
" the proportions of lime and sand in composition of mortar, ii. 215.
Mr. Dossie on making of mortar, ii. 215.
Dr. Higgins on ditto, ii. 215.
" lime, ii. 215.
" sand, ii. 216.
Of the mixture of mortar, ii. 216.
Ditto for fine and coarse work, ii. 216.
Of substitutes for sand and stone-lime, ii. 217.
Of rules for determining the proportions in mixing, ii. 217.
Of the crystallization of mortar, ii. 218.
Mortar, Hydraulic, ii. 218.
Of the materials used, ii. 218.
Analysis of different hydraulic lime-stones, ii. 218.
Of puzzolana, ii. 218.
Cement stone, ii. 219.
Analysis of various kinds, ii. 219.
Mortar, *mixing, blending, and beating of*, ii. 219.
Mortar, White, ii. 219.
Mortar, *for Cisterns*, ii. 219.
Mortar, *for Sundials*, ii. 220.
Mortar-Mill, ii. 220.
Mortise, or Mortice, ii. 220.
Carpentry, i. 82.
Joinery, ii. 56.
Mortise Lock, ii. 220.
Mortuary, ii. 220.
Mosaic, or Mosaic Work, ii. 220.
Description of, ii. 220.
Difference between Mosaic and Marquetry, ii. 220.
Marquetry, ii. 117.
Inlaying, ii. 12.
Origin of Mosaic, ii. 220.
On its application to the decoration of buildings by the ancients, ii. 220.
Moorish Architecture, ii. 211.
Pictures in Mosaic, ii. 220.
Florentine work, ii. 220.
Mosque, ii. 221.
Description of, ii. 221.
Moorish Architecture, ii. 211.
Motion, *Local*, ii. 221.
Motion, *Absolute*, ii. 221.
Movement, ii. 221.
Mould, *Glaziers'*, ii. 221.
Mould, *Masons'*, ii. 221.
Moulds, *Plumbers'*, ii. 221.
Mouldings, ii. 221.
Of Grecian and Roman, ii. 221.
Technical terms for different kinds of mouldings, and their form, ii. 221.
Apophoyge, i. 10.
Cavetto, i. 122.
Cymatium, i. 225.
Echinus, i. 326.
Ovolo, ii. 250.
Quarter Round, ii. 354.
Scape, ii. 408.
Scotia, ii. 409.
To describe the Roman ovolo, ii. 222.

To describe the cavetto, ii. 222.
" sima reversa that shall touch a straight line at the points of contrary flexure, ii. 222.
" a sima recta to touch a straight line at the points of contrary flexure parallel to a line given in position, ii. 222.
" the Grecian ovolo, two tangents being given, as also their points of contact, ii. 222.
The same data being given, to describe the Grecian ovolo, supposing the point of contact to be the extemity of one of the axes, ii. 222.
Norman Architecture, ii. 237.
Gothic Architecture, i. 464.
Moulding Plane, ii. 223.
Plane, ii. 299.
Tools, ii. 494.
Mouldings, *Raking*, ii 223.
Raking Mouldings, ii. 359.
Mouth, ii. 223.
Mullions, ii. 223.
Multilateral, ii. 223.
Multiplication, ii. 223.
Muniment House, ii. 223.
Munnions, ii. 223.
Mullions, ii. 223.
Mural, ii. 223.
Mural Arch, ii. 223.
Muses, ii. 223.
Museum, ii. 223.
Mutilated Cornice, ii. 223.
Mutilated Roof, ii. 223.
Roof, ii. 374.
Mutilation, ii. 223.
Mutule, ii. 223.
Doric Order, ii. 293.
Mylassense Marmor, ii. 223.
Mynchery, ii. 223.
Myron, ii. 223.

Nails, ii. 224.
Description of various kinds, ii. 224.
Nail-head Moulding, ii. 224.
Naked Flooring, ii. 224.
Of different kinds of joists, ii. 224.
Of single and double flooring, ii. 224.
Of girders and trusses, ii. 225.
To construct the plain raftering of a floor, by joining together rafters that otherwise would not extend across the given space, so that the whole extent of the area may be perfectly level; and to estimate by calculation, the pressure upon the whole, and upon the parts separately, ii. 225.
Naked of a Wall, ii. 230.
Naos, or Nave, ii. 230.
Napier's Bones, or Rods, ii. 230.
Narthex, ii. 230.
Nattes, ii. 230.
Natural Beds, ii. 230.
Nave, ii. 230.
Naumachia, ii. 230.
Use and description of, ii. 230.
Nebule, ii. 231.
Neck, ii. 231.
Neefs, Peter, ii. 231.
Negative Quantities, ii. 231.
Nerves, ii. 231.
Net, or Rete, ii. 231.
Envelope, i. 387.
Soffit, ii. 434.
Net Measure, ii. 231.
Net Masonry, ii. 231.
Masonry, ii. 117.
Stone Walls, ii. 464.
Newel, ii. 231.
Niche, ii. 231.
Description of, in Pantheon, Rome, ii. 231.
" Ruins of Palmyra, ii 232.
" Temple of Balbec, ii. 232.
" Temple of Jupiter, Spalatra, ii. 232.
" niches in the pointed style of architecture, ii. 232.
Niche, *in Carpentry*, ii. 232.
Theory and construction of, ii. 232.
The plan, or springing-rib, which forms the top of the cylindric back, and the front rib, which is the segment of a circle, being given; to form the moulds of the back ribs, ii. 233.
To find the length required for any rib, ii. 233.
The plan of a niche in a circular wall being given, to find the front rib, ii. 233.
The plan and elevation of an elliptic niche being given, to find the curve of the ribs, ii. 233.
To range the ribs of the niche, ii. 234.
Given, one of the common ribs of the bracketing of a cove, to find the angle-bracket for a rectangular room, ii. 234.
Niche, *Angular*, ii. 234.
Niche, *Cul de Four of a*, ii. 234.
Cul de Four, i. 217.
Niche, *Ground*, ii. 234.
Niche, *Round*, ii. 234.
Niche, *Square*, ii. 234.
Niched Column, ii. 234.
Column, i. 179.
Nicomedes, ii. 234.
Nidged Ashlar, ii. 234.
Nogs, ii. 234.
Wood Bricks, ii. 526.
Nogging, ii. 234.
Nogging Pieces, ii. 234.
Nonagon, ii. 234.
Normal Line, ii. 234.
Perpendicular, ii. 276.
Subnormal, ii. 480.
Norman Architecture, ii. 234.
Of its origin and introduction into England, ii. 234.
Connection with the Saxon and Roman style considered, ii. 234.
On application of the term Lombardic to this style, ii.235.
Date of adoption of this style in England, ii. 235.
Of the plans of churches in this style, ii. 235.
" parish churches, ii. 235.
" the walls of buildings, ii. 235.
" arches, ii. 235.
" piers, ii. 236.
" capitals, ii. 236.
" bases, ii. 236.
" arcades, ii. 236.
" doorways, ii. 236.
" windows, ii. 237.
" mouldings, ii. 237.
String-courses, ii. 238.
Of parapets, ii. 238.

Of corbel tables, ii. 238.
" buttresses, ii. 238.
" pilaster slips, ii. 238.
" towers, ii. 238.
" pinnacles, ii. 238.
" porches, ii. 238.
" roofs, ii. 238.
" the transition, or semi-Norman style, ii. 238.
" pointed arches, ii. 238.
" doorways, ii. 239.
" windows, ii. 239.
" Norman ecclesiastics great builders, with list of works, ii. 239.
Description of Norman military structures, ii. 239.
Castle, i. 110.
List of well-authenticated Norman buildings, ii. 240.
Principal works for consultation on Norman architecture, ii. 240.
NOSINGS OF STEPS, ii. 240.
NOTCH-BOARD, ii. 240.
NOTCHING, ii. 240.
NUCLEUS, ii. 240.
NUEL, ii. 240.
Newel, ii. 231.
Staircase, ii. 441.
NUISANCE, ii. 240.
NUISANCE, *Abatement of*, ii. 240.

OAK, ii. 240.
OASIS, ii. 241.
List of most noted, ii. 241.
Description of, ii. 241.
OBELISK, ii. 241.
Derivation of term, ii. 241.
Cleopatra's Needles, i. 167.
Difference between obelisks, ii. 241.
Proportions of, ii. 241.
Antiquity of, ii. 241.
Porphyry, ii. 320.
OBLIQUE LINE, ii. 241.
OBLIQUE ANGLE, ii. 241.
OBLIQUE-ANGLED TRIANGLE, ii. 241.
OBLIQUE ARCHES, ii. 241.
Skew Arch, ii. 431.
Stone Bridge, ii. 463.
OBLONG, ii. 241.
OBSERVATORY, ii. 241.
Of the observatory of Greenwich, ii. 242.
" French observatory, ii. 242.
" Tycho Brahé's, ii. 242.
" Benares, ii. 242.
OBTUNDING, ii. 242.
OBTUSE, ii. 242.
OBTUSE-ANGLED TRIANGLE, ii. 242.
OBTUSE SECTION OF A CONE, ii. 242.
OCHRE, ii. 242.
OCTAGON, ii. 242.
OCTAHEDRON, or OCTAEDRON, ii. 242.
Regular Body, ii. 361.
OCTOGON, ii. 242.
Octagon, ii. 242.
OCTOSTYLE, ii. 242.
ODEUM, ii. 242.
ODOMETER, ii. 242.
ŒCUS, ii. 243.
OFFICES, ii. 243.
OFFSETS, ii. 243.
OGEE, ii. 243.
OGIVES, ii. 243.
OILLETS, OILLETTES, or OYLETS, ii. 243.
OLD RED SANDSTONE, ii. 243.
OLYMPIAN GAMES, ii. 243.
Description of, ii. 243.
Circus, i. 164.
Hippodrome, i. 499.
ONE-PAIR OF STAIRS, ii. 243.
OOLITE, ii. 243.
Roe Stone, ii. 370.
OPAE, ii. 243.
OPENING, ii. 243.
Aperture, i. 10.
OPERA HOUSE, ii. 243.
OPISTHODOMOS, ii. 244.
OPPOSITE ANGLES, ii. 244.
OPPOSITE CONES, ii. 244.
OPPOSITE SECTIONS, ii. 244.
OPTIC PYRAMID, ii. 244.
Perspective, ii. 280.
OPTIC RAYS, ii. 244.
Perspective, ii. 280.
OPTICS, ii. 244.
Treatise on, ii. 244.
ORANGERY, ii. 244.
ORATORY, ii. 244.
ORB, ii. 244.
ORCHESTRA, ii. 244.
Theatre, ii. 485.
ORDER, ii. 244.
Origin and description of, ii. 244.
ORDER ATTIC, ii. 245.
Attic, i. 18.
ORDER, CARYATIC, ii. 245.
Caryatic, i. 107.
ORDER, GOTHIC, ii. 245.
Castle, i. 110.
Gothic, i. 450.
ORDERS, GREEK, ii. 245.
Doric Order, i. 290.
Ionic Order, ii. 18.
Corinthian Order, i. 200.
ORDER, PERSIAN, ii. 245.
Persians, ii. 280.
ORDER OF TEMPLES, ii. 245.
Amphiprostyle, i. 3.
Antæ, i. 8.
Dipteral, i. 272.
Peripteral, ii. 275.
Prostyle, ii. 344.
ORDINANCE, or ORDONNANCE, ii. 245.
Order, ii. 244.
ORDINATES, *in Geometry*, ii. 245.
ORDINATE, *in an Ellipsis*, ii. 245.
ORGANICAL DESCRIPTION OF CURVES, ii. 245.
ORIEL WINDOW, ii. 245.
ORLE, ii. 245.
ORNAMENTS, ii. 245.
ORNAMENTS IN RELIEVO, ii. 245.
ORTHOGONAL FIGURE, ii. 245.
ORTHOGRAPHICAL PROJECTIONS, ii. 245.
Projection, ii. 328.
ORTHOGRAPHY, *in Architecture*, ii. 245.
ORTHOGRAPHY, *External*, ii. 245.
ORTHOGRAPHY, *Internal*, ii. 245.
Perspective, ii. 280.

Section, ii. 412.
ORTHOGRAPHY, *in Geometry*, ii. 245.
ORTHOGRAPHY, *in Fortification*, ii. 245.
OSCULATING CIRCLE, or KISSING CIRCLE, ii. 245.
Curve, ii. 219.
OVA, ii. 246.
OVAL, ii. 246.
Definition of, ii. 246.
Ellipsis, i. 365.
Equations for ovals, ii. 246.
To describe an oval through points, ii. 249.
OVICULUM, ii. 250.
OVOLO, ii. 250.
Mouldings, ii. 221.
OUNCE, ii. 250.
OUTER DOORS, ii. 250.
OUTFALL, or OUTLET, ii. 250.
OUTLINE, ii. 250.
OUT-OF-WINDING, ii. 250.
OUT-TO-OUT, ii. 250.
OUTWARD ANGLE, ii. 250.
OXYGON, ii. 250.

PACE, ii. 250.
PADDLE, ii. 250.
PADDLE HOLES, ii. 250.
Clough Arches, i. 169.
PADDLE WEIRS, ii. 250.
Lock Weirs, i. 109.
PADDOCK, ii. 250.
Description of, ii. 250.
PÆSTUM, ii. 250.
PAGOD, or PAGODA, ii. 250.
Description of, ii. 250.
Chinese Architecture, i. 145.
Examples of, viz.,—Pagoda of Chillambrum, near Porto Novo, on Coromandel coast, and that of Jembikisma, ii. 251.
Indian Architecture, ii. 2.
PAINTERS, *House*, ii. 251.
PAINTING, ii. 251.
Theory of, ii. 251.
Technical terms used in, ii. 251.
PAINTING, *Economical*, ii. 251.
Directions for preparing colours, and mode of applying on wood, ii. 251.
On painting of stucco, ii. 252.
Distemper, i. 273.
Fresco, i. 431.
PALACE, ii. 252.
Notice of the principal palaces, ii. 252.
PALÆSTRA, or PALESTRA, ii. 253.
PALATINE BRIDGE, ii. 253.
PALE, ii. 253.
PALES, or PILES, ii. 253.
PALES *for Building*, ii. 253.
Piles, ii. 294.
PALETTE, ii. 253.
PALING, ii. 253.
PALING FENCE, ii. 253.
PALISADE, ii. 253.
PALISADE, *Turning*, ii. 253.
PALLADIAN ARCHITECTURE, ii. 253.
Italian Architecture, ii. 40.
PALLADIO, ANDREA, ii. 253.
PALLADIUM, ii. 254.
Tradition of, ii. 254.
PALLIER, or PAILLIER, ii. 254.
PALLIFICATION, or PILING, ii. 254.
PALM, iii. 254.
PALMYRA, Ruins of, ii. 254.
Antiquity of, ii. 254.
Description of, ii. 254.
PAMPRE, ii. 255.
PANCARPI, ii. 255.
PANEL, or PANNEL, ii. 255.
PANEL, *in Masonry*, ii. 255.
PANNIER, ii. 255.
Corbel, i. 200.
PANORAMA, ii. 255.
Theory of, ii. 255.
PANORAMIC PROJECTION, ii. 255.
Definitions, ii. 256.
To describe the panoramic curve to given dimensions, ii. 256.
To find the indefinite representation of lines parallel to the original plane, in a plane parallel to the axis of the picture; given the height of the eye, the intersection of the original plane, and the distance of the original plane from the picture, ii. 257.
To describe the representation of a line in a plane perpendicular to the axis of the cylinder; given the seat of the line on the original plane, ii. 257.
Given the indefinite representation G, H, No. 2, of a straight line, to determine the finite portion whose seat is A B No. 1, ii. 257.
PANT, ii. 259.
PANTHEON, ii. 259.
Description of at Rome, ii. 259.
PANTILES, ii. 260.
Tiles, ii. 489.
PANTOMETER, ii. 260.
PAPER, *Drawing*, ii. 260.
Table of different sizes of, ii. 260.
PARABOLA, *in Geometry*, ii. 260.
PARABOLIC ASYMPTOTE, ii. 260.
PARABOLIC CONOID, ii. 260.
Paraboloid, ii. 260.
PARABOLIC CURVE, ii. 260.
PARABOLIC SPIRAL, or HELICOID, ii. 260.
PARABOLOID, ii. 260.
PARADIGRAMMATIZE, ii. 260.
PARADOX. ii. 260.
PARALLEL, ii. 261.
PARALLEL COPINGS, ii. 261.
PARALLEL RIGHT LINES, ii. 261.
PARALLEL MOTION, ii. 261.
PARALLEL PLANES, ii. 261.
PARALLEL RULER, ii. 261.
Instruments, ii. 12.
PARALLEL CUT, ii. 261.
PARALLELOPIPED, ii. 261.
Description of, ii. 261.
Properties of the, ii. 261.
To measure the surface and solidity of a parallelopiped, ii. 261.
Parallelogram, ii. 262.
PARALLELOGRAM, ii. 262.
Properties of, ii. 262.
Pentagraph, ii. 274.
PARAMETER, ii. 262.
Parabola, ii. 260.
PARAPET, or BREASTWORK, *in Fortification*, ii. 262.
PARAPET, *in Building*, i. 262.

Parastata, ii. 262.
Parclose, ii. 262.
Parent, Anthony, ii. 262.
Parget, ii. 263.
Pargeting, ii. 263.
Parker's Cement, ii. 263.
Cement, i. 228.
Mortar, ii. 214.
Parlour, ii. 263.
Parquetry, ii. 263.
Marquetry, ii. 117.
Parsonage, ii. 263.
Parthenon, ii. 263.
Description of, ii. 263.
Partition, ii. 264.
Truss, ii. 508.
Party Walls, ii. 264.
House, i. 514.
Parvis, or Parvise, ii. 264.
Pascal, Blaise, ii. 264.
Passages, ii. 265.
Pastil, or Pastel, ii. 265.
Pastophoria, ii. 265.
Pastoral Staff, ii. 265.
Crozier, i. 213.
Pate, ii. 265.
Paten, ii. 265.
Patera, ii. 265.
Use of in Architecture, ii. 265.
Description of, ii. 265.
Paternosters, ii. 266.
Pavement, ii. 266.
Origin of paving, ii. 266.
Pebble paving, ii. 266.
Rag do., ii. 266.
Purbeck pitchens, ii. 266.
Squared paving, ii. 266.
Guernsey granite, ii. 266.
Heron do., ii. 266.
Mount Sorel stone, ii. 266.
Aberdeen granite, ii. 266.
Tyar Baggar stone, ii. 267.
Foggint, or Devonshire granite, ii. 267.
Haytor do., ii. 267.
White rock, or Cornish granite, ii. 267.
Budle stone, ii. 267.
Whinstone, ii. 267.
Purbeck paving, ii. 267.
Yorkshire do., ii. 267.
Rye gate, or Firestone do., ii. 267.
Newcastle flags, ii. 267.
Portland paving, ii. 267.
Sweedland do., ii. 267.
Marble do., ii. 267.
Flat brick do., ii. 267.
Brick on edge do., ii. 267.
Of rubble and aisler causeway, ii. 267.
Directions for laying do., ii. 267.
" for formation of bed, ii. 267.
Of stones for paving, ii. 267.
" wooden pavement, ii. 268.
" foot-pavements of flagstone, ii. 268.
" slate pavement, ii. 268.
" asphalte do., ii. 268.
Pavement of Terrace, ii. 268.
Pavement, Diamond, ii. 269.
Pavilion, ii. 269.
Pautre, Antony Le, ii. 269.
Pax, ii. 269.
Pedestal, ii. 269.
Pedestal, Tuscan, ii. 269.
" Doric, ii. 269.
" Ionic, ii. 269.
" Corinthian, ii. 269.
" Composite, ii. 269.
" Square, ii. 269.
" Double, ii. 269.
" Continued, ii. 269.
Pedestals of Statues, ii. 269.
Pediment, ii. 270.
Description of, ii. 270.
Parts of a, ii. 270.
Variety of forms of, ii. 270.
Console, i. 192.
Pelasgian, or Cyclopean Architecture, ii. 270.
History of, ii. 270.
Celtic Architecture, i. 124.
Remarkable features in, ii. 270.
Of the first mode, or class of buildings, ii. 270.
" 2nd, do., ii. 271.
" 3rd, do., ii. 271.
" 4th, do., ii. 271.
Description of ruins of Tiryns, ii. 271.
" the propylæa of the Acropolis of Mycenæ, ii. 271.
" treasury of Atreus, near Mycenæ, ii. 272.
Pelecoides, ii. 273.
Pend, ii. 273.
Pendent, or Philosophical Bridge, ii. 273.
Bridge, i. 58.
Pendent, ii. 273.
Pendentive, ii. 273.
Pendentive Bracketing, ii. 273.
Pendentive Cradling, ii. 273.
Method of constructing cradling for, ii. 273.
Penetrale, ii. 273.
Penetralia, ii. 273.
Penitentiary House, ii. 274.
Prison, ii. 323.
Penstock, ii. 274.
Pentadoron, ii. 274.
Brick, i. 44.
Pentagon, ii. 274.
Polygon, ii. 319.
Regular Figure, ii. 361.
Pentagraph, Pantagraph, or Parallelogram, ii. 274.
Description and use of, ii. 274.
Pentastyle, ii. 275.
Pent House, ii. 275.
Pent Roof, ii. 275.
Perambulator, ii. 275.
Description and use of, ii. 275.
Perch, *in land-measure*, ii. 275.
Perch, ii. 275.
Perclose, ii. 275.
Parclose, ii. 262.
Peribolus, ii. 275.
Peridrome, ii. 275.
Perimeter, ii. 275.
Periphery, ii. 275.
Sexagesimal, ii. 424.
Circle, i. 162.
Periptere, ii. 275.
Peristyle, ii. 276.

PERIPTERAL, ii. 275.
PERIRANTERION, ii. 276.
PERISTYLE, ii. 276.
PERISTYLION, ii. 276.
PERISTYLIUM, ii. 276.
PERITHERIDES, ii. 276.
Ancones, i. 6.
PERITROCHIUM, ii. 276.
PERPENDICULAR, ii. 276.
Properties of, ii. 276.
PERPENDICULAR TO A CURVE, ii. 276.
PERPENT STONE, ii. 276.
PERPEYN WALL, ii. 276.
PERRAULT, CLAUDE, ii. 276.
PERRON, ii. 277.
PERRONET, JOHN RODOLPHUS, ii. 277.
PERSEPOLIS, ii. 277.
Description of ruins of, ii. 277.
PERSIAN ARCHITECTURE, ii. 277.
Its history and principal features, ii. 277.
Resemblance to that of India and Egypt, ii. 277.
Observations on the principal ruins, ii. 277.
Description of ruins of Persepolis, ii. 277.
Of the site or platform on which these ruins are situate, ii. 278.
Of the propylon, or entrance to the ruins, ii. 278.
Description of columns of second propylon, ii. 279.
" sculpture on do., ii. 279.
" the palace of forty pillars, ii. 279.
" buildings in the vicinity of palace of forty pillars, ii. 279.
" sculptured tombs, ii. 279.
" pyramid amongst the ruins of Pasargadæ, ii. 279.
Of fire-altars, ii. 279.
List of writers on this subject, ii. 280.
PERSIANS, or PERSIC ORDER, ii. 280.
Caryatic Order, i. 107.
PERSPECTIVE, ii. 280.
History of, ii. 280.
Explanation of principles, ii. 281.
Limits of vision, ii. 283.
Definitions, ii. 283.
To put squares into perspective, ii. 283.
To subdivide the square, ii. 284.
To put a circle into perspective, ii. 284.
" a triangular prism " , ii. 284.
" a cube and cylinder " , ii. 284.
Of shadows, ii. 285.
Machine for perspective drawings, ii. 285.
PERSPECTIVE OF SHADOWS, ii. 286.
Given the vanishing line of a plane, the image of a line insisting upon that plane and its vanishing-point, also the vanishing-point of the sun's rays; to find the shadow of the line, ii. 286.
To find the shadow of a cube, ii. 286.
PERUZZI, BALDASSARE, ii. 286.
PEST HOUSE, ii. 287.
PETER OF COLECHURCH, ii. 287.
PEW, or PUE, ii. 287.
PHALANGÆ, ii. 287.
PHAROS, or PHARE, ii. 287.
Eddystone, i. 328.
Lighthouse, ii. 102.
PHEASANTRY, ii. 287.
PHENGITES, ii. 287.
PHIALS ii. 287.
PHIDIAS, ii. 287.
PIACHE, or PIAZZA, ii. 288.
PIAZZA, ii. 288.
Portico, ii. 321.
PICTS WALL, ii. 288.
Description of, ii. 288.
PICTS HOUSE, ii. 288.
PICTURE, ii. 288.
Varnishing of pictures, ii. 288.
Of paintings in miniature, ii. 288.
To repair cut or torn pictures, ii. 289.
Of cleaning pictures, ii. 289.
To transfer oil paintings to new grounds, ii. 289.
Do., paintings on wood, ii. 290.
PIEDROIT, ii. 290.
Pilaster, ii. 290.
PIER, ii. 290.
PIERS, *in Architecture*, ii. 290
PIERS, *Circular*, ii. 290.
PIERS OF A BRIDGE, ii. 290.
PIGGERY, ii. 290.
PIG-STY, ii. 290.
PILA, or PILES, ii. 290.
Piles, ii. 294.
PILÆ, ii. 290.
PILASTER, ii. 290.
Treatment of, ii. 290.
Projecture of, ii. 290.
Diminution of, ii. 290.
Flues, ii. 290.
Proportions of capitals, ii. 290.
PILASTER, *Demi*, ii. 291.
PILASTERS, *in Ship-building*, ii. 291.
PILASTER MASSES, ii. 291.
PILE, ii. 291.
Piles, ii. 294.
PILE, *among Architects*, ii. 291.
PILE DRIVER, ii. 291.
Description of simple machines, ii. 291.
To estimate power of, ii. 291.
Description of machine for large works, ii. 291.
" machine used at Westminster Bridge, ii. 292.
" machine to cut off heads of piles for level platform, ii. 292.
" machine to draw piles, ii. 293.
Theory of Mr. Valoue's engine, ii. 293.
Atmospheric pile-driving, Dr. Pott's system, ii. 294.
Adopted at Goodwin Sands, ii. 294.
Nasmyth's steam-hammer, ii. 294.
Description of its action, ii. 294.
PILE-PLANKS, ii. 294.
Piles, ii. 294.
PILE SHEETING, ii. 294.
PILES, ii. 294.
Uses of, ii. 295.
Formation of, ii. 295.
Square gauge, or guide-piles, ii. 295.
Cast-iron piles, ii. 295.
Ewart's piles, ii. 295.
Description of works at the Brunswick Wharf, ii. 294.
Screw-pile, ii. 296.
Origin of do., ii. 296.
Pile Driving, ii. 294.
PILLAGE, ii. 297.
PILLAR, ii. 297.
Of different kinds of, ii. 297.

Description of Pompey's pillar, ii. 297.
PINION, ii. 298.
PINNACLE, ii. 298.
PINNING, ii. 298.
PINNING-UP, ii. 298.
PIPE, ii. 298.
PISCINA, ii. 298.
PISCINA, or PROBATICA, ii. 298.
PISCINA, or LAVATORY, ii. 298.
PISCINA, *in Ecclesiology*, ii. 298.
PISÉ, ii. 298.
PIT OF A THEATRE, ii. 298.
PITCH, ii. 298.
PITCHING-PIECE, ii. 298.
PIX, ii. 298.
PLACARD, ii. 298.
PLACE BRICKS, ii. 298.
Brick, i. 46.
PLAFOND, or PLATFOND, ii. 299.
Ceiling, i. 122.
PLAIN ANGLE, ii. 299.
PLAIN FIGURE, ii. 299.
PLAIN TILES, or PLANE TILES, ii. 299.
PLAIN TRIANGLE, ii. 299.
PLAIN TRIGONOMETRY, ii. 299.
PLAN, ii. 299.
PLAN, *in Architecture*, ii. 299.
PLAN, *Geometrical*, ii. 299.
PLAN, *Perspective*, ii. 299.
PLAN, *Raised*, ii. 299.
Elevation, i. 364.
PLAN OF A BASTION, ii. 299.
PLAN, *in Ship-building*, ii. 299.
PLANCERE, ii. 299.
PLANE, ii. 299.
Use of, ii. 299.
Description of, ii. 299.
Different kinds of, ii. 299.
Mode of using, ii. 300.
Description of the long plane, ii. 301.
" the shooting plane or jointer, ii. 301.
" the smoothing-plane, ii. 301.
" rebating-plane, ii. 301.
" the moving fillister, ii. 301.
" the sash fillister, ii. 302.
" the plough, ii. 302.
Tools, ii. 494.
PLANE, *in Geometry*, ii. 302.
Circle, i. 162.
Parabola, ii. 260.
PLANE, *Horizontal*, ii. 302.
Perspective, ii. 283.
PLANE, *Inclined*, ii. 302.
PLANE, *Objective*, ii. 302.
PLANE, *Perspective*, ii. 302.
PLANE, *Vertical*, ii. 302.
Perspective, ii. 283.
PLANE TABLE, ii 302.
PLANIMETRY, ii. 303.
PLANING MACHINE, ii. 303.
Description of General Bentham's, ii. 303.
" Bramah's, ii. 303.
" Mr. Bevan's, ii. 304.
PLANISPHERE, ii. 304.
Projection, ii. 328.
Of the plane of projection, ii. 305.
Of the perspective plane, ii. 305.
PLANK, ii. 305.
PLANK-HOOK, ii. 305.
PLANK SHEERS, or PLAN SHEERS, ii. 305.
PLANTING, ii. 305.
PLASTER, ii. 305.
PLASTER OF PARIS, ii. 305.
Gypsum, i. 484.
Of crude Plaster of Paris, ii. 305.
" burnt do., ii. 305.
" taking casts in do., ii. 305.
" the fluid appearance of, when heated over the fire, ii. 305.
Coagulating properties of, ii. 305.
Experiments on, ii. 305.
Expansion of during the process of hardening, ii. 306.
Plaster for floors, ii. 306.
PLASTER FLOORS, ii. 306.
Mode of making, ii. 306.
PLASTERER, ii. 306.
Tools used by, ii. 306.
Technical terms used by, ii. 306.
Plastering, ii. 307.
Measurement of work, ii. 306.
PLASTERING, ii. 307.
Description of work, ii. 307.
Lime, ii. 107.
Plaster of Paris, ii. 305.
Lime and hair, or coarse stuff, ii. 307.
Fine stuff, ii. 307.
Trowelled, or bastard stucco, ii. 307.
Gauge stuff, ii. 307.
Lathing, ii. 307.
Laying, ii. 307.
Pricking-up, ii. 307.
Lathing, laying, and set, ii. 307.
Lathing, floating, and set, ii. 307.
A screed, ii. 307.
The set to floated work, ii. 308.
Rendering and set, or rendering, floated, and set, ii. 308.
Trowelled stucco, ii. 308.
Rough casting, or rough walling, ii. 308.
Cornices, ii. 308.
Mode of constructing do., ii. 308.
Ornamenting of do., ii. 309.
On friezes and basso-relievos, ii. 309.
Capitals to columns, ii. 309.
Use of Bailey's compo for walls, ii. 309.
Dr. B. Higgin's patent stucco, ii. 309.
Parker's cement, ii. 310.
Cement, i. 134.
Mortar, ii. 214.
Fresco painting, or staining plastered walls, ii. 310
Of scagliola, ii. 310.
" composition ornament, ii. 310.
" ancient plastering, ii. 310.
Stucco, ii. 480.
PLATBAND, ii. 311.
PLATBAND OF A DOOR OR WINDOW, ii. 311.
PLATBANDS, or FLUTINGS, ii. 311.
PLATE, ii. 311.
PLATE GLASS, ii. 311.
Glass, i. 447.
PLATES, *Ground*, ii. 311.
Ground Sill, i. 482.
PLATFOND, ii. 311.
Soffit, ii. 434.

Platform, ii. 311.
Plinth, ii. 311.
Plinth of a Statue, ii. 311.
Plinth of a Wall, ii. 311.
Plotting, ii. 311.
Instruments for, ii. 311.
Plotting Scale, ii. 311.
Plug and Feather, or Key and Feather, ii. 311.
Eddystone Lighthouse, i. 334.
Plugs, ii. 311.
Plumber, ii. 311.
Tools and utensils required by, ii. 312.
Plumbery, or Plumbing, ii. 312.
Process of smelting lead-ore, and converting same into pigs of lead, ii. 312.
Properties of lead, ii. 312.
Lead, ii. 96.
Casting of sheet lead, ii. 312.
To cast cisterns, ii. 313.
Chinese method of casting thin sheets of lead, ii. 313.
Of milled lead, ii. 313.
To cast pipes, ii. 313.
Soldering, ii. 314.
Directions for covering terraces, &c., ii. 314.
" for making gutters, ii. 314.
" " reservoirs, ii. 314.
Of pumps, ii. 314.
Table for calculating weight of work by dimensions of same, ii. 314.
Plummet, Plumb-Rule, or Plumb-Line, ii. 315.
Pluteus, ii. 315.
Plyers, ii. 315.
Plymouth Marble, ii. 315.
Podium, ii. 315.
Point, ii. 315.
Point, *Accidental*, ii. 315
Point, *in Geometry*, ii. 315.
Point, *in Perspective*, ii. 315.
Point, *in Physics*, ii. 315.
Point, *Conjugate*, ii. 315.
Point, *Objective*, ii. 315.
Point of Contrary Flexures, ii. 315.
Point of Distance, ii. 315.
Point of Reflection, ii. 315.
Point of Sight, ii. 315.
Point of View, ii. 315.
Point, *Visual*, ii. 315.
Visual, ii. 519.
Pointed Arch, ii. 315.
Architecture, i. 14.
Pointed Architecture, ii. 315.
Origin of, ii. 316.
Gothic Architecture, i. 450.
Bishop Warburton on origin of, ii. 316.
Sir James Hall, do., ii. 316.
Mr. Murphy, do., ii. 316.
Various other writers upon do., ii. 316.
Comparison of opinions, ii. 317.
Intersecting arches, ii. 317.
Invented by the Goths, ii. 317.
" by the Saracens, ii. 317.
Last opinion combated, ii. 317.
The Pointed arch not the only characteristic to be considered, ii. 318.
By what European country first adopted, ii. 318.
Points, *Proportion of Mathematical*, ii. 318.
Polishing, ii. 318.
Pollard, ii. 318.
Polycletus, ii. 318.
Polychromy, ii. 318.
Polyfoil, ii. 319.
Polygon, ii. 319.
Similar, ii. 430.
Polygon, *General Properties of*, ii. 319.
Table of areas of polygons and their perpendiculars, from the centre to one of the sides, ii. 319.
Polygram, ii. 319.
Polyhedron, or Polyedron, ii. 319.
Polyhedron's Figure, ii. 319.
Polyhedron, ii. 319.
Polystyle, ii. 319.
Pomel, ii. 319.
Pompeii, ii. 319.
Situation of, ii. 319.
Description of Torre del Greco, ii. 319.
" Pompeii, ii. 320.
" Cicero's Pompeianum, ii. 320.
Pompeion, ii. 320.
Pompey's Pillar, ii. 320.
Pillar, ii. 297.
Poppy-head, ii. 320.
Porch, ii. 320.
Atrium, i. 18.
Different terms for various kinds of porches, ii. 320.
Of Norman porches, ii. 320.
Galilee, i. 437.
Cathedral, i. 118.
Church, i. 151.
Porphyry, ii. 320.
Description of, ii. 320.
Of horn-stone porphyry, ii. 320.
" felspar do., ii. 321.
" Sienitic do., ii. 321.
" pitch-stone do., ii. 321.
" clay do., ii. 321.
Portable Bridge, ii. 321.
Bridge, i. 61.
Portail, ii. 321.
Portal, ii. 321.
Port Crayon, ii. 321.
Portcullis, ii. 321.
Portici, ii. 321.
Description of Herculaneum, ii. 321.
Portico, ii. 321.
Lacunaris, ii. 92.
Of ancient porticos, ii. 321.
Porticos, ii. 321.
Description of various at Rome, ii. 321.
Portland Stone, ii. 322.
Position, *in Architecture*, ii. 322.
Position, *in Geometry*, ii. 322.
Post, ii. 322.
Post Crown, or King-Post, ii. 322.
Crown Post, ii. 215.
Post and Paling, ii. 322.
Post and Railing, ii. 322.
Postern, ii. 322.
Posticum, ii. 322.
Postique, ii. 322.
Postscenium, or Parascenium, ii. 322.
Pot Metal, ii. 323.
Powderings, ii. 323.
Power, ii. 323.
Force, i. 420.

Pozzolana, ii. 323.
Pozzolana, ii. 346.
Practice, ii. 323.
Cross Multiplication, i. 213.
Praxiteles, ii. 323.
Preaching Cross, ii. 323.
Preceptory, ii. 323.
Preparation, ii. 323.
Presbytery, ii. 323.
Preserving of Timber, ii. 323.
Seasoning Timber, ii. 410.
Timber, ii. 490.
Price Book, ii. 323.
Prick Post, or Queen Post, ii. 323.
Queen Post, ii. 354.
Prime Figure, ii. 323.
Priming, ii. 323.
Principal Brace, ii. 323.
Principal Point, ii. 323.
Perspective, ii. 283.
Principal Rafters, ii. 323.
Principal Ray, ii. 323.
Perspective, ii. 283.
Priory, ii. 323.
Prism, ii. 323.
Prismoid, ii. 323.
Prison, ii. 323.
Mr. Howard's recommendations as to situation and arrangments of prisons, ii. 324.
Description of Millbank Prison, ii. 324.
" Pentonville Prison, ii. 325.
The penitentiary congress of Brussels, propositions of, ii. 326.
Of the arrangement of the building, ii. 326.
" a central observatory, ii. 326.
" the cells, ii. 326.
" special cells, ii. 327.
" heating and ventilation, ii. 327.
" chapels, ii. 327.
" parlours, ii. 327.
" domestic service, administration, lodging of persons employed in prisons, ii. 327.
Description of City prison, Holloway, ii. 327.
Problem, ii. 328.
Producing, ii. 328.
Profile, ii. 328.
Projection, ii. 328.
Definitions, ii. 329.
Propositions, ii. 329.
Given a point on a plane inclined to the plane of projection, to find the orthography or projection of the point, ii. 330.
To find the projection of a straight line in the original plane, ii. 330.
To find the orthographical projection of an angle, ii. 330.
The indefinite projection of a straight line being given, to find the projection of any original point therein, ii. 330.
To find the projection of a given triangle, ii. 330.
Do. do. parallelogram, ii. 330.
To find the representation of a regular pentagon, ii. 330.
Given the intersecting line and the projection of one of the angles of a pentagon, and the projected length of one of the sides, to project the whole figure, ii. 330.
To find the projection of a circle, ii. 330
Do. do. of a segment of do., ii. 330.
To find the projection of an ellipsis, the axis being given, ii. 330.
Any two conjugate diameters of an ellipsis being given; to find the representation of the ellipsis, ii. 331.
To find the projection of any point in space upon a plane given in position, and to determine the distance of the point from the plane, ii. 331.
Supposing a tetraedral, or three-sided solid angle to be placed with one of its sides upon the plane of projection, and one of the other two sides, and the two inclinations adjoining that side, with the intersection of that side to be given; to find the projection of the given side, and the intersection of the remaining side upon the plane of projection, ii. 331.
Given the representation of a point situate in a plane whose original is given; to find the representation of a line from the original point perpendicular to the original plane, ii. 331.
Given the representation of the intersection of a line with the original plane, and the seat in and inclination of the line to the original plane; to find the representation of the line, ii. 331.
Given the representation of one side of a parallelopiped with the inclination of the plane, and the other dimension perpendicular to the original of that plane; to find the representation of the whole solid, supposing the planes of the original solid at right angles to each other, ii. 331.
To find the inclination of two adjoining planes of the regular solids, ii. 331.
To project the dodecaedron, ii. 332.
To divide the representation of a circle into parts representing the original circle divided into equal parts, ii. 332.
To find the orthographical representation of a water-wheel, ii. 332.
To project a straight line in a plane, supposing the plane which contains the line to be wrapped round the surface of a cylinder, ii. 332.
To project any line upon the surface of a cone, ii. 332.
Projection of wheels, ii. 333.
Given the seat and altitude of a line on a plane, and the intersection of the plane with another plane at a given angle; to find the sun's seat on such plane, as also its angle of altitude, ii. 333.
Given the seat and altitude of the sun's rays on a plane, and the angle which the seat of a line parallel to the plane of projection makes with the seat of the sun's rays; to determine the inclination of the plane of shade obstructed by the original line towards the plane of projection, ii. 333.
Given the seat and altitude of a line, and the seat and altitude of the sun's rays; to determine the shadow of the line on that plane, ii. 333.
Given the inclination of a line to two planes at right angles to each other; to find the seat of the line on each of the planes and the intersection of the planes, ii. 334.
Practical examples of shadows, ii. 334.
To find the shadow of a rectangular prism attached to a wall; one of the sides of the prism coinciding with the surface of the wall, ii. 334.
To find the shadow of a cantiliver, formed as in the last example; the plane of elevation being placed obliquely to the surface on which the shadow is thrown, ii. 334.
To find the shadow of a rectangular ring, ii. 334.

Given the sun's seat and inclination on the plane of the horizon, and the intersection of two planes at right-angles with each other, and perpendicular to the horizon, to find the representation of the sun's rays on each of the vertical planes, ii. 334.
To find the representation of the shadow on a prismatic solid by a plane cutting the prism perpendicular to its arrises; given, the elevation of the prism on a plane parallel to its arrises, and parallel to one of its sides, as also the figure of the plane which throws the shadow with the section of the surfaces of the prism on that plane, and likewise the sun's rays both on the plane and on the elevation, ii. 335.
To find the indefinite shadow of a line perpendicular to the horizon on an inclined plane; given the inclination of the plane to the horizon, and the seat of the sun's rays, the intersection of the inclined plane, with the horizon being parallel to the intersection of the plane of representation and the horizon, ii. 335.
To find the shadow of a plane rectilinear figure intersecting another plane figure, a point through which the shadow is to pass on the plane which receives the shadow, and the orthography of the rays of the luminary, being given, ii. 335.
Given the orthography of a determinate line, and the indefinite representation of its shadow, also the orthography of the sun's ray, to find the limits of the shadow, ii. 335.
To find the shadow of a chimney-shaft on the roof of a house, ii. 335.
A cylinder being capped with a square abacus jutting alike over each of the sides, to find the representation of the shadow, the elevation and plan being given, as also the plan and elevation of the sun's rays. ii. 336.
A cylinder being capped with another concentric cylinder, to find the representation of the shadow, ii. 337.
Projection, *Stereographical*, ii. 337.
Stereography, ii. 443.
Projection of Shadows, ii. 337.
Shadows, ii. 424.
Projecture, ii. 337.
Prolate, ii. 337.
Pronaos, ii. 337.
Proportion, i. 337.
Entablature, ii. 387.
Proportional Compasses, ii. 337.
Description of, ii. 337.
Compasses, i. 185.
Instruments, ii. 13.
To set the proportional compasses in the ratio of a line divided into any two parts, ii. 337.
Given, any number of lines, A B, C D, &c., to find a series of other lines which will have the same ratio in every two corresponding lines; given, one line *a b*, of the series required, corresponding to A B of the series given, ii. 338.
To divide a given line in the same proportion as another given line is divided, ii. 338.
To divide a straight line in continued proportion; given the extreme part, ii. 338.
Given two straight lines tending to an inaccessible point, and a point E in position, to draw a straight line through the last named point, so that all the three straight lines may have the same point of concourse, ii. 338.
Given two straight lines tending to an inaccessible point, and any number of points in position not in a straight line, to draw a right-line through each of the points tending to the same point, ii. 338.
Given, the representation of the end of a right cylinder and the vanishing-line of the plane of that end, through a given point in any perpendicular, to draw the representation of the other end of the cylinder, ii. 338.
Given the representation of any point on the picture and the intersecting and vanishing lines of the plane it is in, to find the height of a representative line. the original of which is parallel to the picture, ii. 339.
To construct the scales of sines for the proportional compasses, ii. 339.
To draw the representation of a house by making the centre of the picture the dividing point, having the dimensions of the building given, ii. 340.
Given, the vanishing-line of a plane, its centre and distance, and the inclination of a line in that plane to the intersection, to find the vanishing-point of the line without drawing any lines in the vanishing plane, in order to find the vanishing-point of the original line as given in position to the intersecting line, ii. 340.
To find the vanishing-point of a line, the radial of which makes a greater angle with the primary radial than 45°, the vanishing-line and its centre being given, as also the primary radial, ii. 341.
Given, the angle made by the radials of any two original lines with each other, and the angle which one of them makes with the primary radial, to find a dividing point common to the same measures or scales, so as to cut off a portion from the indefinite representation of each line, such that the portions may be re presentations of the two original lines, ii. 342.
Given, the sun's altitude on a plane, the height of a line and the length of its shadow on that plane, the orthographical representation of a cornice, with a section of the same, as also the seat of the sun's rays, to find the shadow of the cornice, ii. 342.
The representation of a cylinder with a sqaure abacus or cap being given, to find the shadow of the cap upon the cylindric surface, the axis of the cylinder being parallel to the plane of projection, also the shadow of a line perpendicular to the axis of the cylinder, and in a plane passing along the said axis and through the luminary, ii. 342.
To describe the logarithmic spiral by a series of points found in a curve; the centre and two opposite points in a straight line passing through the centre, being given in the curve, ii. 343.
To draw the representation of the meridians of a solid of revolution upon a plane, parallel to the axis of the solid; given an axal section, that is, a section of the solid, passing along the axis upon a plane parallel to the said axis, ii. 343.
Propylæa, ii. 343.
Propylon, ii. 344.
Proscenium, ii. 344.
Prostyle, ii. 344.
Prostypa, ii. 344.
Prothyris, ii. 344.
Console, i. 192.
Prothyrum, ii. 344.
Protractor, ii. 344.
Description of, ii. 344.
Directions for use of, ii. 344.
Protractor, *Improved*, ii. 344.
Pseudo-Dipteral, ii. 344.

Pseudo-Peripteral, ii. 344.
Pteroma, ii. 344.
Puddling, ii. 344.
Pug-Piling, ii. 344.
Pugging, ii. 344.
Pulley, ii. 345.
Description, ii. 345.
Technical terms used in connection with, ii. 345.
Method of arranging, ii. 345.
Doctrine of the, ii. 345.
Pulley Mortise, ii. 346.
Pulpit, ii. 346.
Pulpitum, ii. 346.
Pulvinaria, ii. 346.
Pulvinated, ii. 346.
Punchion, or Puncheon, ii. 346.
Punchion, *with sculptors and others*, ii. 346.
Punchion, or Punchin, *in Carpentry*, ii. 346.
Post, ii. 322.
Punchion, *in Machinery*, ii. 346.
Punt, ii. 346.
Purbeck Stone, ii. 346.
Purfled, ii. 346.
Purlins, ii. 346.
Puteal, ii. 346.
Putlogs, or Putlocks, ii. 346.
Putty, ii. 346.
Puzzolana, or Pozzolana, ii. 346.
Properties of, ii. 346.
Pycnostyle, ii. 347.
Pyramid, ii. 347.
Definition and derivation of, ii. 347.
Description of the three pyramids of Memphis, ii. 347.
Pyramids of Saccara, ii. 349.
Description of tomb of Porsenna at Clusium in Italy, ii. 349.
Egyptian Architecture, i. 351.
Mexican Architecture, ii. 201.
Pyramid, *Properties of the*, ii. 349.
" To measure the surface and solidity of a, ii. 349.
" Frustum of, ii. 349.
Frustum, i. 435.
Pyramid, *Truncated*, ii. 349.
Truncated, ii. 508.
Pyramidoid, ii. 349.

Quadra, ii. 350.
Quadræ, ii. 350.
Quadrangle, ii. 350.
Quadrant, ii. 350.
Quadrature, ii. 350.
Quadrels, ii. 350.
Quadrifores, ii. 350.
Quadrilateral, ii. 350.
Quariporticus, ii. 350.
Quarrel, ii. 350.
Quarry, ii. 350.
Of boring to ascertain the presence of the material sought, ii. 350.
Limestone, ii. 350.
Of the Kentish quarries, ii. 350.
" Common rag-stone, ii. 351.
" Hassocky stone, ii. 351.
" Petworth marble, ii. 351.
" Chalk, localities where found, ii. 351.
" Granite do. do., ii. 351
Of Free-stone, localities where found, ii. 352.
" Flag-stone, do. do., ii. 352.
" Slate, do. do., ii. 352.
Quarry, *in glass*, ii. 353.
Quarry Cart, ii. 353.
Quarry Waggon, or Truck, ii. 353.
Quarrying, ii. 353.
Quarry, ii. 350.
Quarrying Slates and Stones, ii. 354.
Description of manner of cutting and classifying slates, ii. 354.
Of quarrying stone, ii. 354.
Tools used in quarrying, ii. 354.
Quarrying Tools, ii. 354.
Quarryings, ii. 354.
Quarterings, or Quarters, ii. 354.
Quarter Partitions, ii. 354.
Quarter Round, ii. 354.
Quatre-Foil, ii. 354.
Queen Post, ii. 354.
Quick Lime, ii. 354.
Properties of, ii. 354.
On making of mortar, ii. 355.
Proportions of lime and sand, ii. 355.
Principles to be observed in fixing the proportions, ii. 355.
Crystallization of the lime, ii. 355.
Use of the sand, ii. 355.
Sufficiency of water, and proper incorporation of materials necessary, ii. 356.
Water to be retained for length of time, ii. 356.
Nature of mortar, ii. 356.
Lime cement employed by the ancients, ii. 356.
Perfect calcination of the lime-stone necessary, ii. 356.
Proportion of sand dependent on the nature of the lime, ii. 357.
Maceration of the lime before working up, ii. 357.
Limes of chalk, and lime stone or marble, ii. 367.
Other substances used in mortar, ii. 357.
Sir Humphrey Davy on lime cements, ii. 358.
Hydraulic cements, puzzolana and tarras, ii. 358.
Parker's cement, ii. 358.
Conversion of mortar into carbonate of lime, ii. 358
Cement, i. 128.
Lime Stone, ii. 107.
Mortar, ii. 214.
Plastering, ii. 307.
Quire, ii. 358.
Choir, i. 150.
Quirk, ii. 358.
Quirk Mouldings, ii. 358.
Quoin, or Coin, ii. 358.
Coin, i. 175.
Quoins, ii. 358.

Rabbet, or Rebate, ii. 358.
Rebate, ii. 360.
Rabbet Plane, ii. 358.
Plane, ii. 301.
Rabbeting, or Rebating, ii. 358.
Rack, ii. 358.
Radius, ii. 358.
Rafters, ii. 358.
Roof, ii. 375.
Curb Roof, i. 217.
Mechanical Carpentry, ii. 143.
Rag Stone, ii. 358.

Quarry, ii. 350.
RAIL, ii. 358.
RAILING, ii. 359.
RAILWAY, or TRAM ROAD, or DRAM-ROAD, or WAGGON-WAY, ii. 359.
Origin and progress of, ii. 359.
RAIN-WATER PIPE, ii. 359.
RAISER, ii. 359.
Staircasing, ii. 441.
RAISING-PIECES, or REASON-PIECES, ii. 359.
RAKING, ii. 359.
RAKING-MOULDING, ii. 359.
RAMMED EARTH BUILDINGS, ii. 359.
Pise, ii. 298.
RAMP, ii. 359.
RAMPANT ARCH, ii. 359.
RAMPART ARCH, ii. 359.
RAMPART, or RAMPIER, *in fortification*, ii. 359.
RAMPART, *in Civil Architecture*, ii. 360.
RAMPS, ii. 360.
RANGE, or RANGING, ii. 360.
RASP, ii. 360.
RATE, ii. 360.
House, i. 514.
RAVELIN, ii. 360.
READING DESK, ii. 360.
Eagle, i. 312.
REBATE, or RABBET, ii. 360.
RECESS, ii. 360.
RECIPIANGLE, or RECIPIENT ANGLE, ii. 360.
RECTANGLE, ii. 360.
RECTANGULAR, ii. 360.
RECTANGULAR, or RIGHT-ANGLE TRIANGLE, ii. 361.
Triangle, ii. 496.
RECTIFICATION, ii. 361.
RECTILINEAR, or RIGHT-LINED, ii. 361.
RECTORY, ii. 361.
REDANS, ii. 361.
REDOUBT, or REDOUBTE, ii. 361.
REDUCTION, ii. 361.
REFECTORY, ii. 361.
REFLEX, or REFLECT, ii. 361.
REGLET, or RIGLET, ii. 361.
REGRATING, ii. 361.
REGULA, ii. 361.
REGULAR FIGURE, ii. 361.
REGULAR BODY, or PLATONIC BODY, ii. 361.
REGULAR ARCHITECTURE, ii. 361.
REINS OF A VAULT, ii. 361.
Vault, ii. 515.
REJOINTING, ii. 361.
RELATION, ii. 361.
RELIEVO, RELIEF, or EMBOSSMENT, ii. 361.
Basso-Relievo, i. 31.
RELIEVO, *in Architecture*, ii. 362.
RELIEVO, *in painting*, ii. 362.
RENAISSANCE, ii. 362.
Italian Architecture, ii. 40.
Tudor Architecture, ii. 509
RELIQUARY, ii. 362.
RENDERING, ii. 362.
Pargeting, ii. 263.
Plastering, ii. 307.
REPAIRING, ii. 362.
REREDOS, ii. 362.
RESERVOIR, ii. 362.
RESISTANCE, or RESISTING FORCE, ii. 362.
RESISTANCE OF SOLIDS, ii. 362.
RESISTANCE OF THE FIBRES OF SOLID BODIES. Theory of the, ii. 362.
Table of relative resistances, or strengths of wood and other bodies, ii. 364.
RESOLUTION OF FORCES, ii. 365.
Forces, i. 421.
RESPOND, ii. 365.
RESAULT, ii. 365.
RETAINING WALL, ii. 365.
RETICULATED, ii. 365.
RETICULATED WORK, ii. 365.
RETRENCHMENT, *in Architecture*, ii. 365.
RETRENCHMENT, *in Fortification*, ii. 365.
RETURN, ii. 365.
RETURN BEAD, ii. 395.
REVELS, ii. 365.
REVOLUTION, ii. 365.
Cone, i. 188.
RHOMB, ii. 365.
Rhombus, ii. 365.
RHOMBOIDES, ii. 365.
RHOMBUS, or RHOMB, ii. 365.
RIB, ii. 365.
RIBBING, ii. 365.
RIBET, ii. 365.
RIBS, ii. 365.
RIDGE, ii. 365.
RIDGE TILE, ii. 365.
Tile, ii. 489.
RIGGEN, ii. 365.
RIGHT ANGLE, ii. 365.
ROADS, ii. 365.
Of ancient Roman, ii. 365.
McAdam on road-making, ii. 366.
On the elasticity and hardness of roads, ii. 367.
Of foundations for roads, ii. 367.
Of materials for upper coat of a road, ii. 367.
Cleansing of roads, ii. 368.
Experiments in do, ii. 368.
Relative superiority of cube granite and macadamized roads considered, ii. 368.
Of tram roads, ii. 369.
Of wooden roads, ii. 369.
Table of costs of various kinds of roads, ii. 369.
ROD, ii. 370.
ROE STONE, or OOLITE, ii. 370.
ROLL MOULDING, ii. 370.
ROLLS, or ROLLERS, ii. 370.
ROMAN ARCHITECTURE, ii. 370.
Of early Roman buildings, ii. 370.
Progress under the kings, ii. 370.
Rebuilding of the city, ii. 370.
Of roads and aqueducts, ii. 370.
Villas of the Romans, ii. 370.
Marble first used instead of brick, ii. 370.
Introduction of Grecian art, ii. 370.
Of theatres, ii. 371.
Works executed in the reign of Julius Cæsar, ii. 371.
Progress of architecture in reign of Augustus, ii. 371.
Buildings of Nero's time, ii. 371.
Of the Coliseum, ii. 371.
Buildings of the time of Titus, ii. 371.
Do. do, Trajan, ii. 371.
Do. do, Hadrian, ii. 371.
Rebuilding of Jerusalem, ii. 371.
Decline of Roman architecture, ii. 371.

Introduction of Byzantine style, ii. 371.
Comparative merits of Greek and Roman architecture, ii. 372.
Employment of the arch, ii. 372.
Of the Pantheon, an example of the introduction of the dome, ii. 372.
Various other examples of the circular form, ii. 372.
Adoption of this form for tombs, ii. 373.
Examples of ditto, ii. 373.
Circular temple at Balbec, ii. 373.
Characteristics of Roman architecture, ii. 373.
Pantheon, ii. 259.
Amphitheatre, i. 3.
Balbec, i. 25.
Palmyra, ii. 254.
Corinthian Order, i. 200.
Doric Order, i. 302.
Ionic Order, ii. 18.
Roman Order, ii. 373.
Tuscan Order, ii. 513.
ROMAN ORDER, ii. 373.
Composite Order, i. 185.
Order, ii. 244.
Composition of, ii. 374.
Table showing proportions of this order, ii. 374.
ROMANESQUE ARCHITECTURE, ii. 374.
Roman Architecture, ii. 370.
Byzantine Architecture, i. 68.
Lombardic Architecture, ii. 109.
Saxon Architecture, ii. 400.
Norman Architecture, ii. 234.
ROOD, ii. 374.
ROOD BEAM, ii. 374.
ROOD LOFT, ii. 374.
ROOD SCREEN, ii. 374.
ROOD TOWER, ii. 374.
ROOF, ii. 374.
Of early roofs, ii. 374.
Different forms of, ii. 375.
Definitions of technical terms, ii. 375.
If a heavy body A B C D be suspended by any two inclined strings D E and C F, in a vertical plane, a right line drawn through the intersection perpendicular to the horizon, will pass through the centre of gravity of the body, ii. 376.
Given the position in which a body should be placed, and the position of a plane supporting the body at one end, to find the position of another plane to support it at another given point, and to find the pressure on the planes, the weight of the body being given, ii. 376.
In any roof constructed with two equal rafters only, as the height of the roof is to half the breadth of the building, so is half the weight of the roof to the horizontal thrust, or lateral pressure, ii. 377.
If a rafter bear any weight, or have a weight uniformly diffused over it, the force tending to break it is equal to the cosine of elevation multiplied into the weight divided by the radius, ii. 377.
To prevent the rafters of a roof with a tie-beam from bending in the middle, and to remove lateral pressure from the walls when there is no beam, ii. 377.
If a roof be constructed with two equal rafters, with a tie extending from the bottom of each, to an intermediate point in the opposite rafter, and the ties halved together at their intersection, so as to form with the rafters a quadrilateral and two triangles; to find the force tending to break the rafters, ii. 378.
To remove the lateral pressure of a roof without any intermediate beam, brace, or strut, ii. 378.
Given the construction of a roof of which not more than three timbers meet at the same junction, and a force in the direction of any one of the timbers, to find the forces communicated to the other timbers, so that the roof shall be in equilibrio, ii. 379.
Given, the lengths of the rafters of a roof, and their angles of position, to find those angles that require ties, and those which require struts, ii. 379.
To discover the effect of bracing the angles of a roof flat on the top, supported by puncheons at the bottom of the rafters to accommodate a semicircular ceiling within, ii. 369.
Mode of constructing roofs, ii. 380.
Strength of materials, ii. 380.
Description of roof of—
" Chapel of Greenwich hospital, ii. 381.
" S. Paul's Covent Garden, ii. 381.
" Old Drury Lane Theatre, ii. 381.
" Covent Garden Theatre, ii. 381.
" Present Drury Lane Theatre, ii. 381.
" Church of St. Martin in the Fields, ii. 381.
" Basilica of St. Paolo fuori le murà, ii. 382.
" Croydon Railway Station, London, ii. 382.
" Christ's Hospital, ii. 382.
" Exeter Hall, ii. 382.
" St. George's Hall, Liverpool, ii. 383.
To find the scantling of a king-post, ii. 383.
" a queen post, ii. 383.
" tie-beams, ii. 383.
" principal rafters, ii. 383.
" when there is a king-post in middle, ii. 383.
" when there are two queen-posts, ii. 383.
" straining-beams, ii. 383.
" struts and braces, ii. 383.
" purlins, ii. 384.
" common rafters, ii. 384.
Description of roof of riding-house, Moscow, ii. 384.
Of roof designed by Bettancourt, ii. 384.
Of roofs of 16th century by Philibert de Lorme, ii. 384.
Example of do., at Pantheon, Oxford-street, ii. 384.
Colonel Emy's improvements on Philibert's roof, ii. 384.
Description of the earliest roof of this kind erected at Marac, near Bayonne, ii. 384.
Construction of roof of transept at Great Exhibition, ii. 385.
Description of M. Laver's system of construction of roofs, ii. 385.
Of open Gothic roofs of Middle Ages, ii. 386.
Examples of a later date, ii. 386.
Hammer-beam roofs of 15th and 16th century, ii. 386.
Description of roof at Hampton Court, ii. 386.
" Westminster Hall, ii. 386.
Of iron roofs, ii. 387.
Roof of arrival and departure-shed, Euston Grove, ii. 387.
Roof of engine-house, Camden Town, ii. 387.

Examples of iron roofs, ii. 387.
Description of roof of Geological Museum, Piccadilly, ii 388.
" " Palm House, Kew Gardens, ii. 388.
" " over railway-station, Lime-street, Liverpool, ii. 388.
Nasmyth's fire proof flooring and roofing, ii. 389.
Of the coverings of roofs, ii. 389.
Table showing the weight per square of 100 feet for different kinds of covering, ii. 390.
Construction of domes, ii. 390.
Of the dome of St. Paul's, London, ii. 391.
Dome, i. 275.
Curb Roof, i. 217.
Vaulting, ii. 515.
Mechanical Carpentry, ii. 143.
Roof, Hipped, ii. 391.
Hip Roof, i. 496.
Roofing, ii. 391.
Room, ii. 391.
Apartment, i. 8.
Building, i. 65.
Rose, ii. 391.
Rose Window, ii. 391.
Rostrum, ii. 391.
Rotondo, or Rotunda, ii. 391.
Rough Cast, or Rough Casting, ii. 391.
Plastering, ii. 308.
Round Church, ii. 391.
Examples of, ii. 391.
Origin of this form, ii. 391.
Round Towers, ii. 392.
Dimensions and construction of, by Mr. Petrie, ii. 392.
On the origin and use of, ii. 392.
Examples of in Ireland, ii. 393.
" Scotland, ii. 393.
" France, ii. 393.
Rubble Work, ii. 393.
Rudenture, ii. 393.
Ruderation, ii. 393.
Ruins, ii. 393.
Rule, or Ruler, ii. 393.
Rule, Parallel, ii. 393.
Parallel, ii. 261.
Instruments, ii. 12.
Rule, *Carpenter's Joint*, ii. 394.
Use of the Carpenter's Joint, ii. 394.
Instruments, ii. 17.
The breadth of any surface, as board, glass, &c., being given, to find how much in length will make a square foot, ii. 394.
Use of the table at the end of the board-measure, ii. 394.
Use of the line of timber-measure, ii. 394.
Sliding Rule, ii. 434.
Rule, *Bow*, ii. 394.
Ruler, *Parallel*, ii. 394.
Instruments, ii. 12.
Rustic, ii. 394.
Rustic Chamfered, ii. 394.
Rustic Coins, ii. 394.
Quoins, ii. 358.
Rustic Frieze, ii. 394.
Frieze, i. 434.
Rustic Order, ii. 394.
Rustic Work, ii. 394.
Rustic Work, *Frosted*, ii. 394.
Rustic Work, *Vermiculated*, ii. 394.

Sacellum, ii. 395.
Sacrarium, ii. 395.
Sacringe, or Sanctus Bell, ii. 395.
Sacristy, or Vestry, ii. 395.
Saddle backed Coping, ii. 395.
Sag, or Sagging, ii. 395.
Sagitta, *in Architecture*, ii. 395.
Sagitta, *in Geometry*, ii. 395.
Sagitta, *in Trigonometry*, ii. 395.
Saint Peter's, ii. 395.
Of the Circus of Caius formerly occupying the present site of St. Peter's, ii. 395.
Description of the Basilica Vaticana, ii. 395.
Of the different architects engaged on the New Basilica, ii. 395.
Bramante, i. 43.
Bonarotti, i. 38.
Description of the exterior, ii. 395.
" interior, ii. 396.
Of the altar called the confessional of the apostles, ii. 396.
Of bronze canopy erected over ditto by Urban VIII., ii. 396.
Of the grand cupola, ii. 396.
" galleries for exhibiting sacred relics, ii. 396.
" grotto Vaticani, ii. 396.
" piazza of the Vatican Basilica, ii. 397.
" Egyptian Obelisk in the centre of do., ii. 397.
" fountains in do., ii. 397.
Saliant, ii. 397.
Sally, ii. 397.
Sally Ports, or Postern Gates, ii. 397.
Saloon, ii. 397.
Sanctuary, ii, 397.
Chancel, i. 141.
Sand, ii. 397.
Puzzolana, ii. 346.
Sand Stone, ii. 398.
Of red sand stone, ii. 398.
Sangallo, Antonio de, ii. 398.
Sap, *in Building*, ii. 398.
Sap, *in Military Art*, ii. 398.
Sapheta, ii. 398.
Soffit, ii. 434.
Saracenic Architecture, ii. 398.
Moorish Architecture, ii. 208.
Sarcophagus, ii. 398.
Sash, ii. 398.
Sash Frame, ii. 398.
Construction of, ii. 398.
Saw, ii. 399.
Of the pit saw, ii. 399.
" bow saw, ii. 400.
" ripping saw, ii. 400.
" half ripper, ii. 400.
" hand saw, ii. 400.
" panel saw, ii. 400.
" tenon saw, ii. 400.
" sash saw, ii. 400.
" dovetail saw, ii. 400.
" compass saw, ii. 400.
" key-hole, or turning saw, ii. 400.
Saw-Pit, ii. 400.
Sawyers, ii. 400.

Saxon Architecture, ii. 400.
Its origin, ii. 400.
History and early examples, ii. 400.
St. Martin's, Christ Church, Canterbury, ii. 400.
St. Paul, London, ii. 401.
St. Andrew, Rochester, ii. 401.
Westminster Abbey, ii. 401.
Timber Church at York, ii. 401.
Church at Southwell, Notts, built by Paulinus, ii. 401.
Church at Barton-on-Humber, built by St. Chad, ii. 401.
First introduction of glazed windows into England, ii. 401.
Church of polished stone at Ripon, ii. 401.
Church at Hexham, ii. 401.
Monasteries of Monkwearmouth and Jarrow, ii. 401.
Abbey of Malmsbury, ii. 401.
Church of St. Peter, York, rebuilt, ii. 401.
Cathedral, i. 115.
New Church at York, ii. 401.
St. Peter, Oxford, erected by Grimbald, ii. 402.
Cathedral at Winchester, ii. 402.
" Durham, ii. 402.
Monasteries erected during St. Dunstan's episcopate, ii. 402.
Number of churches erected during the Saxon period, ii. 402.
Their appearance, mode of construction, &c., ii. 402.
Mode of building divided into two classes, ii. 402.
Description of churches built of timber, ii. 402.
Greenstead Church, Angre, Essex, ii. 403.
Traditions respecting body of St. Edmund, ii. 403.
Introduction of stone churches, ii. 403.
Manner in which they were built, ii. 403.
Consecration of heathen temples to Christian worship, ii. 403.
Of the existence of such temples in Britain previous to St. Augustine's appearance, ii. 403.
Ancient Roman churches in Britain, ii. 403.
Progress of architecture in Britain, after the Roman manner, ii. 404.
Form of Saxon churches, ii. 404.
Of the present existence of buildings of a date prior to the Conquest, ii. 404.
Church at Iver, Bucks, an instance of ditto, ii. 404.
As to the existence in England of a style distinct from Norman, prior to the Conquest, ii. 405.
Church at Earls-Barton, Northamptonshire, ii. 405.
" Barton-on-Humber, Lincolnshire, ii. 405.
" of Kirkdale, Rydale, North Riding of Yorkshire, ii. 405.
Saxon inscription therein, ii. 405.
Ditto, Aldborough Church, Yorkshire, ii. 406.
Ditto, found at Deerhurst and Jarrow, ii. 406.
Date of churches at Jarrow and Monkwearmouth, ii. 406.
Church at Brixworth, in Northamptonshire, ii. 406.
Architectural peculiarities of the Saxon style, ii. 406.
Lombardic Architecture, ii. 109.
Of Saxon masonry, ii. 406.
" arches, ii. 407.
" imposts, ii. 407.
" doorways, ii. 407.
" windows, ii. 407.
" vaulting, ii. 407.
List of churches in which Saxon remains are supposed to exist, ii. 407.
Church, i. 179.
Scabellum, ii. 407.
Scaffold, ii. 407.
Scagliola, ii. 408.
Plastering, ii. 310.
Scale, ii. 408.
Instruments, ii. 15.
Plotting Scale, ii. 311.
Scalene Triangle, ii. 408.
Scamilli Impares, ii. 408.
Pedestal, ii. 269.
Scamozzi, Vicenzo, ii. 408.
Scandulæ, ii. 408.
Scandularii, ii. 408.
Scantling, ii. 408.
Scantling, *in Masonry*, ii. 408.
Scape, ii. 408.
Scapple, ii. 408.
Scarfing, ii. 408.
Carpentry, i. 90.
Constructive Carpentry, i. 194.
Scenography, ii. 408.
Scenography of a Pyramid, ii. 408.
Scheme, ii. 408.
Scheme Arch, or Skene Arch, ii. 408.
Arch, i. 12.
Schofeet ii. 408.
Soffit, ii. 434.
Scholium, ii. 408.
Sciagraphy, or Sciography, ii. 408.
Scima, ii. 408.
Mouldings, ii. 221.
Scolloped Moulding, ii. 409.
Scopas, ii. 409.
Scotia, ii. 409.
Mouldings, ii. 221.
Scratch Work, ii. 409.
Screen, ii. 409.
Rood Screen, ii. 374.
Screen, ii. 409.
Screw, ii. 409.
Treatise on, ii. 409.
Scribing, ii. 409.
Scribing, *in Joinery*, ii. 409.
Scroll, ii. 409.
Volute, ii. 519.
Sculpture, ii. 409.
Scutcheon, ii. 409.
Scyrium Marmor, ii. 410.
Sealing, ii. 410.
Seasoning Timber, ii. 410.
By immersion in water, ii. 410.
The unfitness of such timber for use, and disadvantages resulting from such practice, ii. 410.
Directions for dry-seasoning, ii. 410.
Directions to be observed in laying floors with timber that has been first soaked in water, and then exposed to the summer sun, ii. 410.
Particulars to be attended to in seasoning wood, ii. 410.
Charring of timber, ii. 410.
Observations of Mr. Wilson on seasoning of timber, ii. 410.
Langton's method of do., ii. 411.
Of smoke-drying and charring of timber, ii. 411.
On Kyan's patent, ii. 411.
" Sir W. Burnett's, ii. 411.
Secant, ii. 411.
Secretarium, ii. 411.
Sacristy, ii. 395.

Section of a Building, ii. 412.
Section of a Solid, ii. 412.
Stereotomy, ii. 444.
Sections, *Conic*, ii. 412.
Conic Sections, i. 189.
Sections of Cylinders, ii. 412.
Cylinders, i. 221.
Sector, ii. 412.
Instruments, ii. 16.
Sector of a Circle, ii. 412.
Sedilia, ii. 412.
Segment, ii. 412.
Segment of a Circle, ii. 412.
Mensuration, ii. 167.
Sell, ii. 412.
Sill, ii. 430.
Semicircle, ii. 412.
Circle, i. 162.
Semicircular Arches, ii. 412.
Septizon, or Septizonium, ii. 412.
Sepulchral, ii. 412.
Sepulchral Chapel, ii. 412.
Chantry Chapel, i. 142.
Sepulchral Column, ii. 412.
Column, i. 182.
Sepulchral Monument, ii. 412.
Sepulchre, ii. 412.
Seraglio, ii. 412.
Serlio, Sebastiano, ii. 412.
Sesspool, or Cesspool, ii. 413.
Set-off, ii. 413.
Setting, ii. 413.
Setting-out Rod, ii. 413.
Severy, ii. 413.
Sewer, ii. 413.
Sewerage, ii. 413.
Necessity of attending to general principles, ii. 413.
Objects to be effected by drainage, ii. 413.
Application of sewage as a manure, ii. 413.
Of liquid sewage manure, ii. 414.
Of dry do., ii. 414.
De-odorization and disinfection of sewage, ii. 414.
Commercial value of sewage-manure, ii. 414.
Difficulty of getting rid of sewage, ii. 414.
Employment of natural channels, ii. 414.
Of tidal rivers, ii. 414.
Methods of proceeding when the sewage is to be applied as a manure in a liquid state, ii. 415.
" in a dry state, ii. 415.
Preparation of preliminary plans, sections, borings, &c., ii. 415.
Methods to be adopted in laying out a system of drainage, ii 416.
Of house and surface-drainage, ii. 416.
Of the proper size, or capacity of sewers, ii. 416.
Experiments on do., ii. 416.
Table showing results of experiments, ii. 417.
Evidence of Mr. Phillips on the size of sewers, ii. 417.
" Mr. Roe " , ii. 418.
Observations on flow of water in the Fleet sewer, ii. 418.
Table of gaugings of sewers, ii. 418.
Comparison as regards the efficiency of large and small sewers, ii. 419.
Experiments on the flow of water through various-sized pipes, ii. 419.
Table showing the quantity of solid matter held in suspension, ii. 420.
Objections against the use of small pipes, ii. 420.
Consideration of objections, ii. 420.
Separation of house and surface-drainage, ii. 420.
Of the employment and proper size of pipes, ii. 420.
" " of brick sewers, ii. 421.
Forms of sewers, ii. 421.
Materials of do., ii. 421.
Of form, &c., of pipe-sewers, ii. 421.
Table showing comparative time of run of water through brick drains and glazed pipes, ii. 422.
Of rate of inclination, ii. 422.
" junctions, ii. 422.
" ventilation of sewers, ii. 423.
" side-entrances, ii. 423.
" gullies, ii. 423.
" house-drainage, ii. 423.
" back and front drainage, ii. 423.
" the size of house-drains, ii. 424.
Sexagesimal, ii. 424.
Sexagon, or Hexagon, ii. 424.
Shadowing, ii. 424.
Directions for preparing paper, ii. 424.
" for mixing Indian ink, ii. 424.
" for drawing outline, ii. 424.
" for laying on shadowing colour, ii. 424.
Shadows, Doctrine of, ii. 424.
To find the shadows upon the surfaces of bodies occasioned by the privation of the sun's rays, ii. 424.
Given the vanishing line of a plane, the vanishing-point of the sun's rays, the vanishing-point of the seat of a ray on the plane, the representation of a point in space, and the representation of the seat of the point in the plane whose vanishing-line is given; to find the representation of the shadow upon the plane of the picture, ii. 424.
Given the inclination of a plane to the plane of the picture, both being perpendicular to the original plane, and the seat and inclination of a straight line in the plane of the horizon; to determine the vanishing-point of the seat of the line on the vertical plane, and the vanishing-point of the line, ii. 425.
To find the shadow of a cylinder lying with its convex surface upon a horizontal plane, ii. 425.
To find the shadow of one cylinder upon another. The cylinder which throws the shadow, and that on which the shadow is thrown, being placed, the former with its end and the latter with its convex surface upon the same horizontal plane, ii. 425.
To find the shadow of a building with a break, ii. 426.
Projection, ii. 328.
To find the vanishing-line of a pole upon several planes, ii. 426.
Of shadows projected from a given point, as by the light of a candle or lamp, ii. 427.
Given the representation of three rectangular planes forming a solid angle; the representation of a point of light or candle, and the seat of the light on one of the planes; to find the seat of the light on the other two planes, ii. 428.
Given the representation of a line perpendicular to the original of the plane, and the vanishing point of the line, and the point where the line meets the plane, a luminous point with its seat also upon the plane; to find the shadow of the line upon the said plane, ii. 428.
Shaft, ii. 428.
Column, i. 179.

To represent a fluted column, the height of the column, its diameter at the bottom, and the ratio of the two diameters being given, ii. 428.
Several methods of drawing columns, ii. 428.
Shaft of a Chimney, ii. 429.
Chimney, i. 144.
Shaft of a King-Post, ii. 429.
Shafted Impost, ii. 429.
Shake, or Shaken, ii. 429.
Shaky, or Shaken, ii. 429.
Sham Door, ii. 429.
Door, i. 288.
Shank, ii. 429.
Sheers, ii. 429.
Sheet Lead, ii. 429.
Plumbery, ii. 312.
Shelves, ii. 429.
Shides, or Shingles, ii. 429.
Shingles, ii. 429.
Shingles, ii. 429.
Shingling, ii. 429.
Slating, ii. 431.
Shoar, or Shore, ii. 429.
Shoar Dead, ii. 429.
Shoaring, ii. 430.
Shoar, ii. 429.
Shoe, ii. 430.
Shoot, ii. 430.
Shooting Board, ii. 430.
Shoulder of a Tenon, ii. 430.
Shouldering Pieces, ii. 430.
Brackets, i. 42.
Shread Head, or Jerkin Head, ii. 430.
Jerkin Head, ii. 55.
Shredings, ii. 430.
Furrings, i. 436.
Shrine, ii. 430.
Shrinking, ii. 430.
Shutters, ii. 430.
Joinery, ii. 68.
Boxings of a Window, i. 41.
Sash Frame, ii. 398.
Side Posts, ii. 430.
Side Timbers, ii. 430.
Purlins, ii. 346.
Side Wavers, ii. 430.
Purlins, ii. 346.
Sill, or Cill, ii. 430.
Sima, ii. 430.
Mouldings, ii. 221.
Sima Inversa, ii. 430.
Mouldings, ii. 221.
Sima Recta, ii. 430.
Mouldings, ii. 221.
Sima Reversa, ii. 430.
Mouldings, ii. 221.
Similar Figures, ii. 430.
Single Floor, ii. 430.
Naked Flooring, ii. 224.
Single Frame and Naked Floor, ii. 430.
Single Hung, ii. 431.
Single-joist Floor, ii. 431.
Single Joists, ii. 431.
Single Measure, ii. 431.
Site, ii. 431.
Skew Arch, ii. 431.
Stone Bridge, ii. 462.
Skew Table, ii. 431.
Skirtings, or Skirting Board, ii. 431.
Skirts, ii. 431.
Skreen, ii. 431.
Skylights, ii. 431.
Slab, ii. 431.
Slate, ii. 431.
Slating, ii. 431.
Different kinds of slates, table of different sizes of slate, together with technical terms by which each size is distinguished, ii. 431.
Of patent slate, ii. 432.
Preparation of slates for roofing, ii. 432.
Preparation of roof for slating, ii. 432.
Mode of laying slates for roofing, ii. 432.
Mode of slating with patent slate, ii. 432.
Of slaters' tools, ii. 433.
Of the saixe, ii. 433.
" ripper, ii. 433.
" hammer, ii. 433.
" shaving-tool, ii. 433.
" strength of slate, ii. 433.
Its applicability to different kinds of work, ii. 433.
Measurement of slaters' work, ii. 433.
Table of comparative sizes and weight of, ii. 433.
Sleepers, ii. 433.
Sliding Rule, ii. 434.
Carpenter's Rule, i. 77.
Examples of use of, ii. 434.
Slit Deal, ii. 434.
Smoothing Plane, ii. 434.
Plane, ii. 299.
Snacket, ii. 434.
Snipe's Bill, ii. 434.
Socket Chisel, ii. 434.
Socle, or Zocle, ii. 434.
Soffita, Soffit, or Sofit, ii. 434.
Soffit, or Sofit, ii. 434.
Soffits, ii. 434.
Envelope, i. 387.
To find the soffit of the opening of a window in a straight wall, ii. 434.
To find the soffit of the opening of a window of the same width as the former, in a circular wall, ii. 434.
To find a circular soffit in flewing jambs, ii. 434.
To find a circular soffit in a circular wall, which is flewing on the jambs, and square at top, ii. 435.
To find a circular flewing soffit in a circular wall, ii. 435.
To find a circular flewing and winding soffit in a straight wall, ii. 435.
To find a cylindrical soffit, cutting obliquely through a straight wall, ii. 435.
To find a cylindrical soffit in a circular wall, ii. 435.
Description of a cono-cuneoidal soffit in a circular wall, ii. 435.
" of a conical soffit in a cylindric wall, ii. 435.
" of a conical soffit in a circular wall, ii. 435.
" of a cuno-cuneoidal soffit in do., ii. 435.
Soils, ii. 436.
Sill, ii. 430.
Soils, *in Roofing*, ii. 436.
Principal Rafters, ii. 323.
Soldering, ii. 436.
Solid, ii. 436.
Dodecahedron, i. 274.
Icosahedron, ii. 1.
Octahedron, ii. 242.

Tetrahedron, ii. 484.
Cube, i. 216.
SOLID ANGLE, ii. 436.
Comparison of solid angles, ii. 436.
SOLID SHOOT, ii. 436.
Water Shoot, ii. 522.
SOLINE, ii. 436.
SORTANT ANGLE, ii. 436.
Salient Angle, ii. 397.
SOSTRATUS, ii. 436.
SOUFFLOT, JAMES GERMAIN, ii. 436.
SOUND BOARD, ii. 436.
SOUND BOARDING, ii. 436.
SPAN, ii. 437.
SPANDREL, ii. 437.
SPANDREL BRACKETING, ii. 437.
Given the plan of a square room to be covered or vaulted with spandrel bracketing, and the vertical section of the cone whose plane passes through the axis of the room, and through the intersection of two adjoining walls; to find the figure of the springing on the walls, so that the faces of the brackets may be in the surface of a solid, formed by revolving the given section from its place in the angle, round the axis of the room, until it makes a revolution, ii. 437.
Given the plan of an oblong room to be covered or vaulted with spandrel bracketing, the ceiling-line and ellipsis inscribed in the plane, and a section of the cove through the diagonal perpendicular to the ceiling-line; to find the spandrels of the bracketing, such that they may be the intersections made by the planes of the four walls, with the curved surface of a solid generated by the given section, moving always perpendicular to the ceiling-line, which passes through the upper extremity of the curve of the generating section and the lower extremity, always in a horizontal plane, ii. 437.
Given the plan of a rectangular room to be covered with spandrel bracketing, supposing the surface of the solid, with which the faces of the brackets are to coincide, to be an ellipsoid, the base of the spandrel solid, a section passing through its axis, ii. 437.
Given the springing line of one of the ends, which is a section perpendicular to the fixed axis; to find the springing-line upon the sides, so that they may be of the same height with that upon the ends, and also the curves of the ribs, ii. 437.
SPAN PIECE, ii. 438.
Collar Beam, i. 175.
SPAN ROOF, ii. 438.
SPECIES OF TEMPLES, ii. 438.
Temple, ii. 438.
SPECIFICATION, ii. 438.
SPECIFIC GRAVITY, ii. 438.
The weight and specific gravity of a body being given; to find its magnitude, ii. 438.
Specific gravity and magnitude of a body being given; to find its weight, ii. 438.
Properties relating to specific gravity, ii. 438.
To find the specific gravity of a body, ii. 438.
" " when the body is heavier than water, ii. 438.
" " when the body is lighter than water, ii. 438.
" " when the specific gravity of the fluid is required, ii. 438.
Table of specific gravities of bodies, ii. 439.
SPERE, ii. 439.
SPHERE, ii. 439.
To find the solidity of, ii. 439.
To find the superficies of, ii. 439.
SPHERICAL BRACKETING, ii. 439.
Plastering, ii. 307.
SPHEROIDAL BRACKETING, ii. 440.
SPHINX, ii. 440.
SPIRAL, ii. 440.
Volute, ii. 519.
SPIRE, ii. 440.
SPITAL, ii. 440.
SPLAYED, ii. 440.
SPRING BEVEL OF A RAIL, ii. 440.
SPRINGED, ii. 440.
SPRINGING COURSE, ii. 440.
SQUARE, ii. 440.
SQUARE SHOOT, ii. 440.
Water Shoot, ii. 522.
SQUARE STAFF, ii. 440.
SQUARING HANDRAILS, 440.
Hand Railing, i. 487.
SQUARING OF A PIECE OF STUFF, ii. 440.
SQUINCH, ii. 441.
SQUINT, ii. 441.
STABLE, ii. 441.
STADIUM, ii. 441.
STAFF BEAD, ii. 441.
STAINED GLASS, ii. 441.
On the early use of, ii. 441.
Stained glass of the Early English period, ii. 441.
" in the Decorated Style, ii. 441.
" of the Perpendicular period, ii. 441.
STAIRCASE, ii. 441.
STAIRS, ii. 441.
Proportions of, ii. 441.
STAIRS, *Straight*, ii. 442.
STAIRS, *Winding*, ii. 442.
STALK, ii. 442.
STALL, ii. 442.
STALL, *a fixed seat*, ii. 442.
STANCHION, ii. 442.
STANCHIONS, or PUNCHEONS, ii. 442.
Studs, ii. 480.
STANDARDS, ii. 442.
STANDARDS, *in Joinery*, ii. 442.
STAPLE, ii. 442.
STARLINGS, ii. 442.
STAVES, *in Joinery*, ii. 442.
STAVES, or ROUNDS, ii. 442.
STAY BAR, ii. 442.
STEEL, ii. 442.
On the tempering of, ii. 443.
Cast steel, ii. 443.
STEEPLE, ii. 443.
STENCH TRAP, ii. 443.
STEPS, ii. 443.
STEREOBATA, or STEREOBATES, ii. 443.
STEREOGRAPHIC PROJECTION OF THE SPHERE, ii. 443.
Stereography, ii. 443.
Stereotomy, ii. 444.
Definitions, ii. 443.
STEREOMETRY, ii. 444.
Cylinder, i. 221.
Globe, i. 449.
Sphere, ii. 439.

Properties of planes and solids demonstrated in 11th book of Euclid's Elements, useful in Stereotomy, ii. 444.
To draw a straight line perpendicular to a plane from a given point in space above the plane, ii. 444.
To erect a straight line at right angles to a given plane, from a given point in the plane, ii. 444.
Properties of solids, ii. 445.
General principles of construction, ii. 445.
In a right-angled trihedral, are given the two sides containing the right angle; to find the acute angles and the side or hypothenuse which subtends the right angle, ii. 445.
Given one of the sides containing the right angle and the angle opposite; to find the remaining side which contains the right angle, ii. 445.
Given one of the sides containing the right angle and the inclination or angle adjacent; to find the remaining side which contains the right angle, ii. 445.
Given two sides and the contained angle; to find the other parts, ii. 445.
The three sides of a spherical triangle being given; to find the angles, ii. 446.
Two angles and a side opposite to one of them being given; to find the other two sides and the remaining angle, ii. 446.
Given two angles and the contained side; to find the other three parts, ii. 446.
Two sides and an angle opposite to one of them being given; to find the three remaining parts, ii. 446.
The three angles of a spherical triangle being given; to find the three sides, ii. 446.
Given the seat of the intersection in space of two planes having a given inclination and the intersection of one of them in a given plane, also the inclination of the common intersection of the two planes to the given plane; to find the intersection of the other plane with the given plane, ii. 447.
Given I N, the intersection of the plane W, with another plane X, and their inclination the seat A B, in the plane X, of a line in space insisting at A, and the inclination of the line to the plane X; to find the section of the line in the plane W, ii. 447.
The same things being given, and the constructive lines remaining as in preceding problem, as also the point *a* the section of the line in space; to find the seat of the line in plane W, and its inclination to the said plane, ii. 447.
Two straight lines tending to an inaccessible point being given through a given point, to draw a third straight line to tend to the same inaccessible point, ii. 448.
Given the meridian A B in the plane of the horizon X, the latitude of the place, the intersection I N, of the plane W, with the horizontal plane X, and the inclination of the plane W to that of the horizon H, to construct a dial in the plane W, ii. 448.
Given the base A N Q R of a pyramid in the plane H, and the whole seat A B of one of its angular lines, the intersection I N of the cutting plane W, and the inclination of the planes W and X; to find the section of the pyramid, ii. 448.
To find the section of a prism, the same things as before being given, ii. 448.
To find the section of a right pyramid, ii. 448.
To find the section when the base of the pyramid is oblique, ii. 448.
To find the section of a right cone, ii. 449.
Description of Plates, ii. 449.
Cylinder, i. 221.
Sterlings, ii. 449.
Stilts, ii. 449.
Stiles, ii. 449.
Stilted Arch, ii. 449.
Stilts, ii. 449.
Stock, ii. 449.
Stone, ii. 449.
Material, ii. 126.
Stone Arch, ii. 449.
Masonry, ii. 117.
Stone Bridge, ii. 449.
Bridge, i. 58.
Equilibrium of arches, ii. 449.
Dr. Hook's application of the figure called the catenarian curve, ii. 450.
On loading for the haunches, ii. 450.
Theory arising from the consideration of the curve as a combination of an infinite number of straight lines, ii. 451.
To describe an equilibrated extrados to a circular arc, ii. 451.
To find an equilibrated intrados, the extrados being given, ii. 451.
The wedge theory, ii. 452.
Application of the theory to the flat arch, ii. 453.
On jointing, ii. 454.
" the backing of an arch, ii. 455.
" friction, ii. 455.
" the lateral pressure likely to be produced by the employment of some kinds of backing, ii. 457.
" the thickness of the arch-stones, ii. 457.
" piers and abutments, ii. 458.
To calculate the amount of friction on the voussoirs in any particular instance, ii. 460.
Dr. Robison's theory, ii. 460.
Method of constructing Westminster Bridge, ii. 460.
Its dimensions, ii. 460.
Removal of Old London Bridge injurious to the foundations of the other bridges, ii. 461.
Dimensions of and manner of constructing Blackfriars' Bridge, ii. 461.
Waterloo Bridge, ii. 461.
London do., ii. 462.
Skew Bridges, ii. 462.
On their first introduction, ii. 463.
Mode of construction, ii. 463.
Stone Columns, ii, 463.
Mode of construction, ii. 463.
Stone Stairs, ii. 463.
Mode of construction, ii. 463.
Stone Walls, ii. 464.
Masonry, ii. 117.
Construction of walls of the ancients, ii. 464.
Stoothings, ii. 464.
Story Posts, ii. 464.
Story Rod, ii. 464.
Stoup, ii. 464.
Straight-jointed Floor, ii. 465.
Straining Piece, or Strutting Piece, ii. 465.
Straining Cill, or Strutting Sill, ii. 465.
Strap, ii. 465.
Strata, ii. 465.
Strength of Materials, ii. 465.
Strength of Timber, ii. 465.

The force which elastic strings or fibrous bodies, &c., exert when drawn or compressed in a direction of their length, is proportional to the increased or contracted space to which they are lengthened or shortened, ii. 465.

If a beam be supported at two ends, and a force or weight applied to the middle of it, the deflection of the beam or space through which it bends, will be as the force applied nearly, ii. 465.

If a solid be supported by 4 forces, of which 2 and 2 are parallel, then in each pair of parallel forces, one force is equal to the other, and its direction contrary, ii. 465.

If instead of the weights I, L, H, as in the last proposition, the points A and D, be supported by two springs A G and D H, in the direction A B and D C, parallel to the horizon, and by a prop D F perpendicular to it, and if A D be divided into any two parts A E and E D, then will P. C D = E D. f + E A. f; that is, the momentum of power is equal to the sum of the momentum of tension and compression where f is the tension of the upper spring, or the compression of the lower, ii. 466.

If a beam be supported by the two ends, and a weight be applied over the middle section, then will the momentum of power occasioned by the weight to overcome the resistance of the beam, be equal to half the weight multiplied into half the length of the beam, ii. 466.

If a beam A B be supported in four points A, B, C, D, and a weight W appended to the middle of the part C D, at F, it will carry twice as much as if it were only supported by the two middle points C, D, ii. 466.

If a weight W, or any force, act perpendicularly to the length of a beam supported at the two extremities A and B, the strain at the section C, on which the force acts, will be equal to the rectangle of the two segments, into the weights divided by the length, that is as $\frac{\text{A C, C B, W}}{\text{A B}}$, ii. 466.

The strain on any section D, of a beam resting on two props A and B, occasioned by a second force, applied perpendicularly upon another section C, is equal to the rectangle of the two extreme segments into the weight divided by the length, that is, $\frac{\text{A C, D B, W}}{\text{A B}}$ equal to the strain at D, ii. 466.

If a weight be equally diffused throughout any part B C of a beam A D, the strain at either end C of the diffused part, is to the strain at the same place from the same weight being suspended there, as A B + A C, to twice A C, ii. 466.

The strain of a prismatic beam, supported at the two ends A and B, by its own weight, at any section C, is equal to the rectangle of the two segments into the weight of the beam, divided by twice its length, that is $\frac{\text{A C, B C}}{2\text{ A B}}$, ii. 467.

If a prismatic beam A B, be fixed in a wall at A, the strain at any section C, D, from its own weight, will be as the square of the distance B, C, of that section from the extremity, ii. 467.

To determine the relative strength of a rectangular prismatic beam A B C D, projecting horizontally from a wall, supposing the beam to be incompressible at the fulcrum, ii. 467.

To determine the relative strength of a prismatic rectangular beam, projecting horizontally from a wall, supposing it to turn round some intermediate axis in the section of fracture, ii. 468.

On Galileo's and Mariotte's doctrines of resistance, ii. 468.

Tables of Belidor's and Buffon's experiments on strength of beams, and deductions therefrom, ii. 469.

Mr. Petit and others upon the subject, ii. 473.

To determine the neutral line, ii. 474.

Mr. Banks' experiments, ii. 475.

Mr. Tredgold's do., ii. 475.

Table showing the cohesion of a square inch of different woods pulled asunder in a direction perpendicular to the length of the fibres, ii. 475.

Do. in the direction of their length, ii. 476.

Table showing the modulus of elasticity of beams pressed in the direction of their length, ii. 476.

Result of experiments by Rennie, ii. 476.

Table of experiments on the strength of woods supported at both ends, ii 476.

Do. supported at one end, ii. 476.

Mr. Telford's experiments on the cohesive force of iron, ii. 477.

Table showing the cohesive force of iron, ii. 477.

Table showing the extension, by a suspended weight, of a wrought-iron bar, 10 feet long, 1 inch square, ii. 477.

Table showing the extension, and permanent set of a cast-iron rod, 10 feet long, and 1 inch square, drawn in the direction of its length, ii. 477.

Table showing the extensions of cast-iron rods, 10 feet long, and 1 inch square, deduced from numerous experiments, and compared with observed compression of bars of the same irons and the same size, cast with them for comparison, ii. 477.

Table showing the compression of a cast-iron bar 10 feet long, and 1 inch square, ii. 478.

Table showing the compression of wrought and cast-iron bars, 10 feet long, and 1 inch square nearly, ii. 478.

Table showing the average breaking weight of bars, 1 inch square, and 3 feet long, ii. 478.

General observations, ii. 478.

Tensile strength of round iron, chain-cable, and ropes, ii. 478.

Transverse strength of a slab of slate from the Penrhyn quarries, ii. 478.

Transverse strength of timber, ii. 478.

Results of experiments made with actual weights on materials used in the Britannia bridge, January, 1848, viz.,

Brickwork, ii. 479.

Sandstone, ii. 479.

Limestone, ii. 479.

Single bricks of different qualities, ii. 479.

STRETCHED-OUT, ii. 479.

STRETCHER, ii. 479.

STRETCHING COURSE, ii. 480.

STRIÆ, ii. 480.

STRIGES, ii. 480.

STRIKING, STICKING, or RUNNING A MOULDING, ii. 480.

STRIKING, ii. 480.

STRIKING A CENTRE, ii. 480.

STRING BOARD, ii. 480.

STRING COURSE, ii. 480.

STRING PIECE, ii. 480.

STRIX, ii. 480.

Struck, ii. 480.
Struts, ii. 480.
Strutting Beam, or Strut Beam, ii. 480.
Strutting Piece, ii. 480.
Straining Piece, ii. 465.
Stucco, ii. 480.
Cement, i. 128.
Mortar, ii. 214.
Plastering, ii. 397.
Studs, ii. 480.
Stud Partitions, ii. 480.
Stud Work, or Brick Nogging, ii. 480.
Brick Nogging, i. 47.
Stuff, ii. 480.
Style, or Stile, ii. 480.
Stylobate, ii. 480.
Sub-Base, ii. 480.
Subnormal, or Super Perpendicular, ii. 480.
Sub-Plinth, ii. 480.
Sub-Principals, ii. 480.
Summer, ii. 480.
Summer-House, ii. 480.
Summer-Tree, ii. 480.
Bressummer, i. 44.
Girders, i. 446.
Sunk Shelves, ii. 480.
Supercilium, ii. 480.
Superstruct, ii. 480.
Superstructure, ii. 480.
Supporters, ii. 480.
Surbase, ii. 480.
Surmounted Arch, ii. 480.
Surveying, ii. 481.
Surveying Wheel, ii. 481.
Perambulator, ii. 275.
Suspension Bridge, ii. 481.
Difference of principle between suspension and arched bridges, ii. 481.
Of early suspension bridges, ii. 481.
Examples of the first suspension bridges erected in England, ii. 481.
Description of Union suspension bridge, Berwick on Tweed, ii. 481.
Description of Telford's bridge over the Menai Straits, ii. 481.
Example of different suspension bridges, ii. 481.
Swallow Tail, ii. 482.
Dove Tail, i. 304.
Swelled Column, ii. 482.
Column, i. 182.
Symbolical Column, ii. 482.
Column, i. 184.
Symmetry, ii. 482.
Systyle, ii. 482.

Tabern, ii. 482.
Tabernacle, ii. 482.
Table, or Tablet, ii. 482.
Table Corbel, ii. 482
Table, *Projecting*, ii. 482.
Table, *Raised*, ii. 482.
Table, *Raking*, ii. 482.
Table, *Rusticated*, ii. 482.
Table, *Water*, ii. 482.
Table, *in Perspective*, ii. 482.
Table of Glass, ii. 482.
Tabled, ii. 482.
Tablet, ii. 482.
Tabling, ii. 482.
Tacks, ii. 482.
Tænia, or Tenia, ii. 482.
Tail, Swallow, ii. 482.
Swallow Tail, ii. 482.
Tail-in, ii. 482.
Tail Trimmer, ii. 482.
Tailing, ii. 482.
Tailoir, ii. 482.
Abacus, i. 1.
Talon, ii. 482.
Talus, ii. 482.
Tambour, ii. 482.
Tangent, ii. 482.
Tank, ii. 482.
Tapering, ii. 482.
Tapestry, ii. 482.
Tarrace, ii. 482.
Terrace, ii. 484.
Tarras, or Terras, ii. 482.
Cement, i. 131.
Mortar, ii. 218.
Plastering, ii. 307.
Tassels, ii. 482.
Taxis, ii. 483.
Teaze Tenon, ii. 483.
Teint, ii. 483.
Telamones, ii. 483.
Atlantes, i. 18.
Persians, ii. 280.
Temoin, ii. 483.
Temones, ii. 483.
Tempered, ii. 483.
Temple, ii. 483.
Origin and uses of, ii. 483.
Situation and arrangement of, ii. 483.
Of idols, ii. 483.
The form of temples, ii. 483.
Of the façade, ii. 483.
Temple in Antis, ii. 484.
Prostyle temple, ii. 484.
Amphi-prostyle do., ii. 484.
Peripteral do., ii. 484.
Dipteral, ii. 484.
Pseudo-dipteral do, ii. 484.
Hypæthral do., ii. 484.
Templet, ii. 484.
Tenaille, ii. 484.
Ten-foot Rod, ii. 484.
Tenon, ii. 484.
Tenon Saw, ii. 484.
Saw, ii. 400.
Tension, ii. 484.
Tension Rod, ii. 484.
Teocalli, ii. 484.
Tepidarium, ii. 484.
Term, ii. 484.
Terminus, ii. 484.
Terra Cotta, ii. 484.
Terrace, ii. 484.
Terrace Roofs, ii. 484.
Terras, ii. 484.
Tarras, ii. 482.
Terre Plain, ii. 484.
Tesselated Pavement, ii. 484.
Mosaic, ii. 220.

Tessera, ii. 484.
Testar, or Testoon, ii. 484.
Testudo, ii. 484.
Testudinal Ceilings, or Roofs, ii. 484.
Tetradoron, ii. 484.
Brick, i. 44.
Tetragon, ii. 484.
Tetrahedron, ii. 484.
Tetraspastus, ii. 485.
Tetrastyche, ii. 485.
Tetrastyle, ii. 485.
Thatch, ii. 485.
Theatre, ii. 485.
Magnitude of, ii. 485.
Abstract of Mr. Wyatt's report of Drury-lane Theatre, ii. 485.
Design of ditto, ii. 485.
Dimensions of stage-openings of several large theatres, ii. 485.
Size of a theatre, ii. 485.
Returns, ii. 485.
Best shape and dimensions for a theatre, as regards sound, &c., ii. 486.
Of theatre of Parma, ii. 488.
" early English theatres, ii. 488.
" height of ceiling, ii. 488.
Dimensions of interior of Drury-lane Theatre, ii. 488.
Amphitheatre, i. 3.
Theodolite, ii. 488.
Theorem, ii. 488.
Theotheca, ii. 488.
Thole, ii. 488.
Tholobate, ii. 488.
Tholus, ii. 488.
Thorough Framing, ii. 488.
Thorough-lighted Rooms, ii. 488.
Threshold of a Door, ii. 488.
Sill, ii. 430.
Throat, ii. 489.
Gorge, i. 450.
Gula, i. 482.
Throating, ii. 489.
Through Stone, ii. 489.
Tie, ii. 489.
Tie Beam, ii. 489.
Tie, ii. 489.
Truss, ii. 508.
Tie Rod, ii. 489.
Tension Rod, ii. 484.
Tierce Point, ii. 489.
Tige, ii. 489.
Tile, ii. 489.
Brick, i. 44.
Different kinds of, ii. 489.
Tile Creasing, ii. 489.
Tiles Encaustic, ii. 489.
Tiling, ii. 489.
Timber, *in Carpentry*, ii. 489.
Timber, ii. 489.
Of structure and growth of trees, ii. 489
Seasoning of Timber, ii. 410.
Best mode of preserving timber, ii. 490
Description of woods, ii. 490.
Of oak, ii. 490.
" beech, ii. 490.
" alder, ii. 490.
" plane-tree, ii. 490.
Of chesnut, ii. 490.
" ash, ii. 490.
" elm, ii. 490.
" accacia, ii. 490.
" poplar, ii. 490.
" fir, ii. 491.
" spruce, ii. 491.
" pine, ii. 491.
" silver fir, ii. 491.
" larch, ii. 491.
Table showing comparative strength, stiffness, and toughness of various woods, ii. 491.
Strength of Materials, ii. 465.
Timber Bridge, ii. 491.
Wooden Bridges, ii. 526.
Timber Measure, ii. 491.
Timber Partitions, ii. 491.
Tin, ii. 491.
Ting, ii. 491.
Chinese Architecture, i. 147.
Tinning, ii. 491.
Tomb, ii. 491.
Earliest methods of disposing of the dead, ii. 491.
Egyptian Architecture, i. 362.
Pyramid, ii. 347.
Sepulchral grottos of Etruria, ii. 492.
Tombs of Campania, ii. 492.
Of tumuli, ii. 492.
Tomb containing bodies of a prince and princess discovered in 50° north latitude, ii. 492.
Pelasgian Architecture, ii. 270.
Discovery of Roman sepulchres—
At Chatham, Kent, ii. 492.
" York, ii. 492.
" Oxfordshire, ii. 492.
Of the tumuli discovered in Britain, ii. 493.
Progress of tomb-building in England, ii. 493.
Do., after reformation, ii. 493.
Mr. Gough's classification of tombs, ii. 493.
Tondino, ii. 493.
Torus, ii. 495.
Tongue, ii. 493.
Tools, ii. 494.
Of Bricklayers', ii. 494.
Of Carpenters', ii. 494.
Joinery, ii. 56.
Plane, ii. 299.
Gage, i. 437.
Saw, ii. 399.
Masons', ii. 494.
Plasterers', ii. 494.
Plasterer, ii. 306.
Plumbers,' ii. 495.
Plumber, ii. 312.
Slaters', ii. 495.
Slating, ii. 433.
Tilers', ii. 495.
Tooth, ii. 495.
Tooth Ornament, ii. 495.
Dog-tooth Moulding, i. 275.
Top Beam, ii. 495.
Collar Beam, i. 175.
Top Rail, ii. 495.
Torsel, or Torsil, ii. 495.
Tassels, ii. 482.
Torus, or Tore, ii. 495.
Torus for a Bulwark, ii. 495.

Tower, ii. 495.
Castle, i. 110.
Church, i. 153.
Cathedral, i. 115.
Gothic Architecture, i. 464.
Round Tower, ii. 392.
Town, ii. 495.
Town-Hall, ii. 495.
Trabs, ii. 495.
Tracery, ii. 495.
Origin of, ii. 495.
Of Plate Tracery, ii. 495.
" Bar " , ii. 495.
" Geometrical Tracery, ii. 495.
" Flowing " , ii. 495.
" Flamboyant " , ii. 496.
Trail, ii. 496.
Trammel, ii. 496.
Transept, ii. 496.
Cathedral, i. 115.
Church, i. 151.
Transition, ii. 496.
Gothic Architecture, i. 450.
Norman Architecture, ii. 238.
Transom, *in Joinery*, ii. 496.
Transom, *a Mullion*, ii. 496.
Transtra, ii. 496.
Transverse, ii. 496.
Transverse Strain, ii. 496.
Transyte, ii. 496.
Trapezium, ii. 496.
Travelling Crane, ii. 496.
Traverse, *to Plane*, ii. 496.
Traverse, *a Gallery*, ii. 496.
Tread of the Step of a Stair, ii. 496.
Trebeation, ii. 496.
Entablature, i. 386.
Trefoil, ii. 496.
Trellis Work, ii. 496.
Tressel, or Trussel, ii. 496.
Trussel, ii. 509.
Triangle, ii. 496.
Triangular Compasses, ii. 496.
Instruments, ii. 13.
Triclinium, ii. 496.
Cyzicene, i. 225.
Triforium, ii. 496.
Triglyphs, ii. 496.
Trigonometry, ii. 496.
Definitions, ii. 496.
On Logarithms, ii. 497.
Trigonometrical formulæ for finding the sine, cosine, tangent, secant, &c., in terms of each other, ii. 499.
To find the sines, cosines, tangents, and secants, for arcs of 30°, 45°, 60°, and 120°, ii. 499.
To transfer their values to circles of different radii, ii. 500.
The sine and cosine of any two unequal arcs of the same circle being given, to find the sine of any multiple of the lesser arc, ii. 500.
To find the sine of an arc in terms of the sine of half the arc, ii. 500.
Formulæ deduced from the above:—
sin. (A + B) + sin. (A — B) = 2 sin. A cos. B, ii. 500.
$\sin. m + \sin. n = 2 \sin \frac{m+n}{2} \cos. \frac{m-n}{2}$, ii. 501.
sin. (A + B) sin. (A — B) = (sin. A + sin. B) (sin. A — sin. B), ii. 501.
sin. $3a = 3 \sin. a - 4 \sin. 3a$, ii. 501.
To find the sine and cosine of an arc in terms of the sine of twice the arc, ii. 501.
The sides of any plane triangle are as the sines of the angles opposite them, ii. 502.
In any plane triangle, as the sum of the two sides is to their difference, so is the tangent of half the sum of the opposite angles to the tangent of half their difference, ii. 502.
In any plane triangle, if a perpendicular be let fall upon the longest side from the opposite angle; then as the sum of the segments of the base is to the sum of the other two sides, so is the difference of the sides to the difference of the segments of the base, ii. 502.
Solutions of three cases of oblique-angled triangles:—
Two angles and a side being given, to find the remaining sides, ii. 502.
Two sides of an angle opposite to one of them being given, to find the other two angles and the remaining side, ii. 503.
Given two sides and the included angle, to find the other two angles and the third side, ii. 503.
Given the three sides, to find the angles, ii. 503.
Application of above analogies, ii. 504.
Given the angles and hypothenuse of a right-angled plane triangle, to find the base and perpendicular, ii. 505.
Given the angles and one side, to find the hypothenuse and other side, ii. 505.
Given the hypothenuse and one side to find the angles and the other side, ii. 506.
Given the base and perpendicular, to find the angles and hypothenuse, ii. 506.
To find the height of an inaccessible object, ii. 507.
" distance between two inaccessible objects ii. 507.
Trilateral, ii. 507.
Trim, ii. 507.
Trimmed, ii. 507.
Trimmed Out, ii. 507.
Trimmer, ii. 507.
Trimming-Joists, ii. 507.
Trine Dimensions, ii. 507.
Tripartition, ii. 508.
Tripod, or Tripos, ii. 508.
Triptic, or Triptych, ii. 508.
Trisection, ii. 508.
Trochilus, ii. 508.
Scotia, ii. 409.
Mouldings, ii. 221.
Trochoid, ii. 508.
Cycloid, i. 221.
Trophy, ii. 508.
Trough, ii. 508.
Trough-Gutter, ii. 508.
Trowel, ii. 508.
Tools, ii. 494.
Trowel Point, ii. 508.
Trugg, ii. 508.
Truncated, ii. 508.
Truncated Cone, ii. 508.
Cone, i. 188.
Truncated Pyramid, ii. 508.
Trunk, ii. 508.
Truss, ii. 508.

Definition of, ii. 508.
Principles of, ii. 508.
Uses of, ii. 508.
Trusses for roofs and centerings, ii. 508.
Technical terms used for different parts of a truss, ii. 508.
Description of plates, ii. 509.
Truss Partition, ii. 509.
Truss Posts, ii. 509.
Truss, ii. 509.
Trussed Beam, Trussed Girders, or Girding Beams, ii. 509.
Girders, i. 446.
Trussed Rafter Roof, ii. 509.
Trussels, or Tressels, ii. 509.
Trussing Pieces, ii. 509.
Try, ii. 509.
Tube, ii. 509.
Tubular Bridge, ii. 509.
Iron Bridge, ii. 35.
Tudor Architecture, ii. 509.
On the application of this term, ii. 509.
Progress of in reign of Henry VII., ii. 509.
" " Henry VIII., ii. 509.
List of edifices erected during this reign, ii. 509.
Plan of mansions erected at this period, ii. 510.
Materials used, ii. 510.
Description of gatehouses, ii. 510.
Of the roofs and ceilings, ii. 510
Roof, ii. 386.
Of the windows, ii. 511.
Description of Hampton Court Palace, ii. 511.
" Thornbury Castle, Gloucestershire, ii. 511.
" mansion at Midhurst, Sussex, ii. 511.
" Hengrave Hall, Suffolk, ii. 511.
" Manor House, East Barsham, Norfolk, ii. 511.
Of Elizabethan, or late Tudor, ii. 512.
Plan of buildings of this reign, ii. 512.
Difference between this and Early Tudor architecture, ii. 512.
General characteristics, ii. 512.
Noted architects of this time, ii. 512.
List of principal mansions of this period, ii. 513.
Description of the half-timbered houses of this time, ii. 513.
List of remaining examples, ii. 513.
House, i. 512.
Tudor Flower, ii. 513.
Tufa, ii. 513.
Tumbling-in, or Trimming-in, ii. 513.
Tun of Timber, ii. 513.
Tunnel, ii. 513.
Turning Piece, ii. 513.
Turret, ii. 513.
Tuscan Order, ii. 513.
Connection of with Roman-Doric, ii. 513.
Vitruvius on, ii. 513.
Palladio on, ii. 514.
Serlio on, ii. 514.
Scamozzi on, ii. 514.
Tusk, ii. 514.
Tympan, ii. 514.
Type, ii. 514.

Umber, ii. 514.
Undecagon, ii. 514.
Undercroft, ii. 514.
Under Pinning, ii. 514.
Ungula, ii. 514.
University, ii. 514.
Uphers, ii. 514.
Upright, ii. 514.
Urbin, or Urbino, ii. 514.
Bramante, i. 43.
Urn, ii. 514.

Vagina, ii. 515.
Valley, ii. 515.
Valley-Board, ii. 515.
Valley-Rafter, ii. 515.
Valley-Rafters, ii. 515.
Sleepers, ii. 433.
Valley Pieces, ii. 515.
Valley Rafters, ii. 515.
Vallum, ii. 515.
Valved, ii. 515.
Vane, ii. 515.
Vanishing Line, ii. 515.
Vanishing Point, ii. 515.
Variation of Curvature, ii. 515.
Variety, ii. 515.
Varnish, ii. 515.
Vase, ii. 515.
Vase of the Corinthian, or Composite Capital ii. 515.
Vases of a Theatre, ii. 515.
Vault, ii. 515.
Vault Cylindric, ii. 515.
Vault in Full Centre, ii. 515.
Vault, *Surmounted*, ii. 515.
" *Surbaise*, ii. 515.
" *Rampant*, ii. 515.
" *Double*, ii. 515.
" *Conic*, ii. 515.
" *Spherical*, ii. 515.
Dome, i. 275.
" *Annular*, ii. 515.
" *Simple*, ii. 515.
" *Compound*, ii. 515.
" *Cylindro-Cylindric*, ii. 515.
" *Groined*, ii. 516.
Groined vaulting in Temple of Peace at Rome, ii. 516.
Gothic Architecture, i. 464.
Stone Bridge, ii. 449.
Extract from Hutton's Mathematics on Vaulting, ii. 516.
Stone-roofing in East Indies, Lieutenant Outram on, ii. 517.
Mode of constructing do., ii. 517.
Material for do., ii. 518.
Vault, *Reins of a*, ii. 518.
Vaulting Shaft, ii. 518.
Vellar Cupola, ii. 518.
Veneer, ii. 518.
Venetian Door, ii. 518.
Venetian Window, ii. 518.
Vent, ii. 518.
Ventiducts, ii. 518.
Ventilation, ii. 518.
Ventilator, ii. 518.
Verge, ii. 518.
Verge Board, ii. 518.
Barge Board, i. 27.
Vermiculated Rustics, ii. 518.
Versed Sine, ii. 518.

Trigonometry, ii. 497.
VERTEX, ii. 518.
VERTEX OF A CONIC SECTION, ii. 518.
VERTICAL ANGLES, ii. 518.
VERTICAL PLANE, ii. 518.
VESICA PISCIS, ii. 518.
VESTIBULE, ii. 518.
VESTMENT, ii. 518.
VESTRY, ii. 518.
Sacristy, ii. 395.
VIADUCT, ii. 519.
VIGNETTE, ii. 519.
VIGNOLA, ii. 519.
VILLA, ii. 519.
House, i. 503.
VISE, ii. 519.
VISUAL POINT, ii. 519.
Point, ii. 315.
VISUAL RAY, ii. 519.
VITRUVIAN SCROLL, ii. 519.
VITRUVIUS, M. POLLIO, ii. 519.
VIVO, ii. 519.
Column, i. 179.
VOLUTE, ii. 519.
Method of describing the logarithmic spiral, ii. 520.
VOUSSOIRS, ii. 521.

WAGGON-HEADED CEILING, ii. 521.
WAINSCOT, ii. 521.
To measure wainscoting, ii. 521.
Carpentry, i. 80.
Joinery, ii. 70.
WALL PLATE, ii. 522.
WALLS, ii. 522.
Materials for constructing, ii. 522.
Stone Walls, ii. 464.
Bricklaying, i. 47.
Technical terms used to signify different kinds of walls, ii. 522.
WALLS, *Abutments in*, ii. 522.
" *Cased*, ii. 522.
" *Emplectum*, ii. 522.
" *Isodomum*, ii. 522.
" *Pseudo-isodomum*, ii. 522.
Building, i. 66.
Pise, ii. 298.
Mensuration, ii. 190.
WATER CLOSET, ii. 522.
WATER SHOOT, ii. 522.
WATER TABLE, ii. 522.
WAY-WISER, ii. 522.
Perambulator, ii. 275.
WEATHER BOARDING, ii. 522.
WEATHERING, ii. 522.
WEATHER MOULDING, ii. 522.
WEATHER TILING, ii. 522.
WEDGE, ii. 522.
Directions in which the power is applied, ii. 522.
Let A B C be a vertical section passing through the centre, and at right angles to the head and sides of any isosceles wedge, also in the plane of this section, and at right angles to its sides A B, B C, and C A, let three powers be applied, such that their directions may all mutually intersect in the axis, and their efforts sustain the wedge in equilibrio, which three powers are as A B, B C, and C A, respectively, ii. 522.
When an impelling power applied to the head of an isosceles wedge, is in equilibrio with the resisting power of a cleft, the angle of which is more acute than that of the wedge inserted, then universally the impelling power applied to the head, the action of the wedge on either side of the cleft, the part thereof which tends to thrust it forward, and the remaining part which tends to tear it asunder, are as twice the sine of half the vertical angle of the wedge, the radius, the sine of the angle contained by the sides of the wedge and cleft, and the cosine of that angle, respectively, the same radius being common, ii. 523.
WEIGHT, *in Mechanics*, ii. 523.
WEIGHT, *in Commerce*, ii. 523.
Weights and measures of Richard I.'s time, ii. 523.
Modern European weights, ii. 523.
Troy weight, ii. 523.
Avoirdupois weight, ii. 523.
Comparison between troy and avoirdupois weight, ii. 523.
Goldsmiths' and Jewellers' weights, ii. 523.
Wool weight, ii. 524.
Weights of Spain, ii. 524.
" Portugal, ii. 524.
" Italy, ii. 524.
" various other countries, ii. 524.
Proportion of the weights of the principal places in Europe, ii. 524.
Proportion of the weights of several places in Europe, compared with those of Amsterdam, ii. 524.
Comparison of English and foreign weights, ii. 524.
German weights, ii. 524.
Dutch, do., ii. 524.
Swedish weights used by Bergman and Scheele, ii. 525.
Correspondence of English weights with those used in France, previous to the Revolution, ii. 525.
To reduce French to English troy weight, ii. 525.
To reduce English troy to Paris weight, ii. 525.
To reduce English avoirdupois to Paris weight, ii. 525.
Table of weights according to new French system, ii. 525.
Measure, ii. 131.
WEIGHTS OF A SASH, ii. 525.
WEIR, ii. 525.
WELCH GROINS, ii. 525.
WELDING, ii. 525.
WELL-HOLE, ii. 525.
WHEEL, ii. 525.
Lever, ii. 97.
WHEEL WINDOW, ii. 525.
Rose Window, ii. 391.
Catherine Wheel Window, i. 120.
WHETSTONE, ii. 525.
WICKET, ii. 525.
WIND BEAM, ii. 525.
Collar Beam, i. 175.
WINDERS, ii. 525.
Stairs, ii. 442.
WINDING STAIRS, ii. 525.
Stairs, ii. 442.
WINDLASS, or WINDLACE, ii. 526.
WINDOWS, ii. 526.
Form of, ii. 526.
Proportions of, ii. 526.
Position of, ii. 526.
Apartment, i. 8.
Building, i. 65.

Casement, i. 108.
House, ii. 503.
Joinery, ii. 68.
Sash Frame, ii. 398.
Skylight, ii. 431.
Tracery, ii. 495.
Gothic Architecture, i. 462.
Window Shutters, ii. 526.
Boxings, i. 41.
Joinery, ii. 68.
Sash Frame, ii. 398.
Wing, ii. 526.
Withs, ii. 526.
Chimney, i. 144.
Wood, ii. 526.
Timber, ii. 489.
Materials, ii. 122.
Mensuration, ii. 195.
Seasoning of Timber, ii. 410.
Strength of Timber, ii. 465.
Wood Bricks, ii. 526.
Wooden Bridges, ii. 526.
Of ancient and simplest form, ii. 526.
" the forces to which a beam supported at either end is subjected, ii. 526.
" framed bridges, ii. 527.
" the Pons Sublicius at Rome, ii. 527.
" the bridge built over the Danube by Trajan, ii. 527.
" of Schauffhausen over the Rhine, ii. 528.
" of St. Clair over the Rhone, ii. 528.
" of Grenelle over the Seine, ii. 528.
Of piers and abutments, ii. 528.
Of the roadways, ii. 529.
Drawbridges, ii. 529.
Theory of a polygonal framing subjected to compression, ii. 529.
Direction of the strain, ii. 530.
Of scarfing, ii. 530.
" tenon and mortise-joint, ii. 530.
" dove-tail joints, ii. 530.
Of king and queen posts, ii. 530.
" the various kinds of forces to which timbers applied to such purposes are subjected, and how to dispose them most advantageously, ii. 530.
Breaking-weight of a beam, ii. 530.
Of resistance to tension and pressure, ii. 531.
Results of experiments on do., ii. 531.
Wooden Column, ii. 531.
Working Drawings, ii. 531.
Wreathed Columns, ii. 531.
Wren, Sir Christopher, ii. 532.
His biography, ii. 532.
" plan for rebuilding London, ii. 532.
" works, ii. 532.
" directions respecting the erection of churches:—
Of the site, ii. 533.
" extra-mural interment, ii. 533.
" the materials, ii. 533.
" capacity and dimensions, ii. 533.
" situation of the pulpit, ii. 533.
Conclusion of biography, ii. 534.

Xenodochium, ii. 534.
Xystos, ii. 534.

Yard, ii. 535.
Mensuration, ii. 164.
Yellow, ii. 536.

Zacco, ii. 536.
Zax, ii. 536.
Zeta, or Zeticula, ii. 536.
Zigzag Moulding, ii. 536.
Norman Architecture, ii. 237.
Zinc, ii. 536.
Zocco, or Zocle, ii. 536.
Zophorus, ii. 536.
Frieze, i. 434.
Zophoric Column, ii. 536.
Zotheca, ii. 536.

THE END

INSTRUMENTS
FOR DRAWING.

PLATE. I

Fig 1 N°1

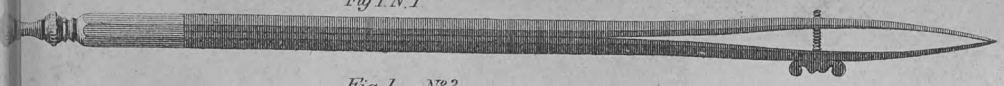


Fig. 1. N°3.

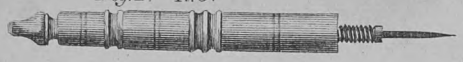


Fig 1 N°2.



Fig. 11.

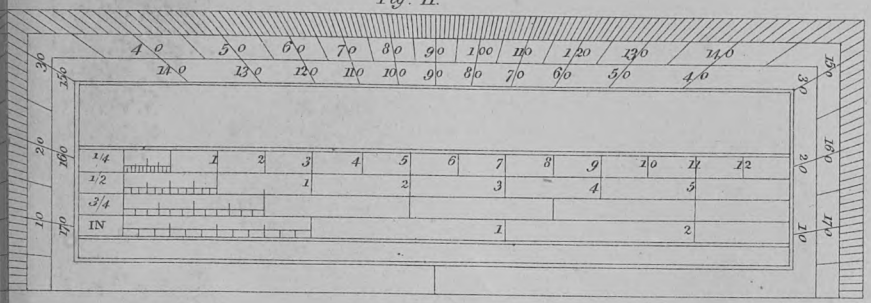


Fig. 10.

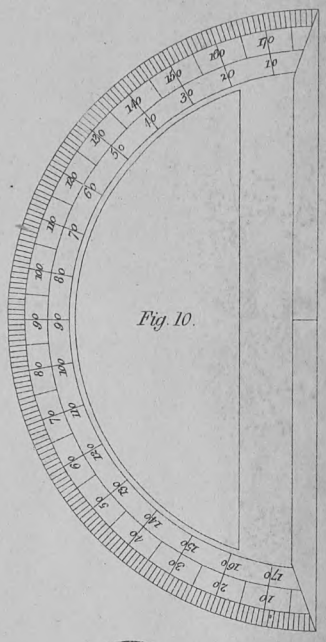


Fig. 12.

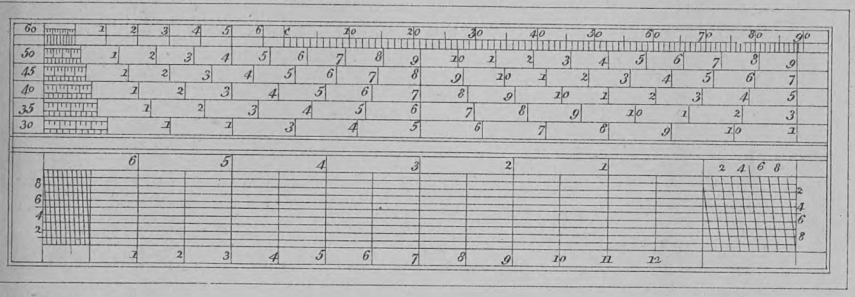


Fig. 14.

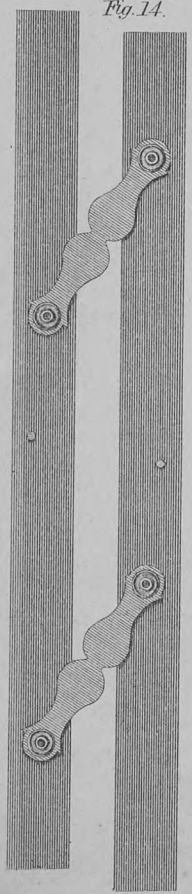


Fig. 15.

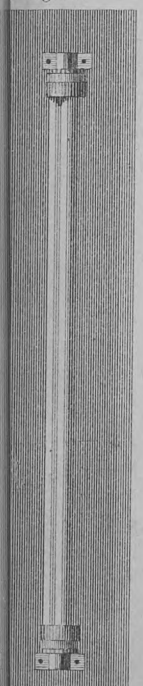


Fig. 13. N°. 2.

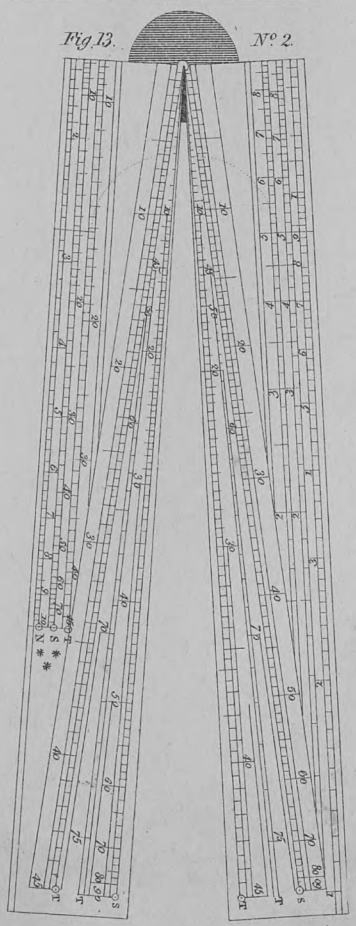
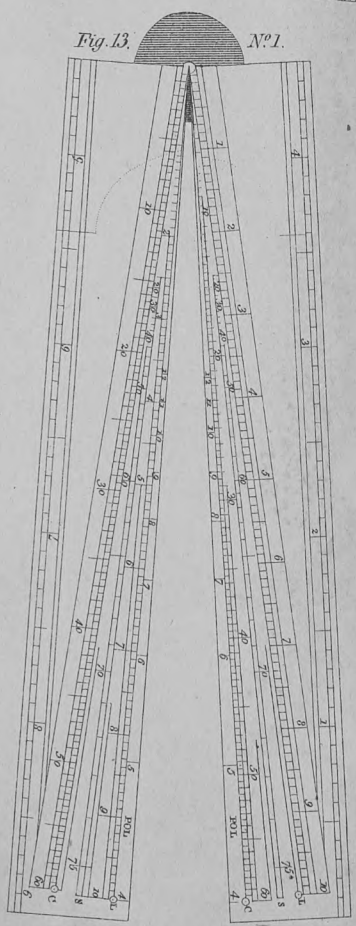


Fig. 13. N°. 1.



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Fig. 11.

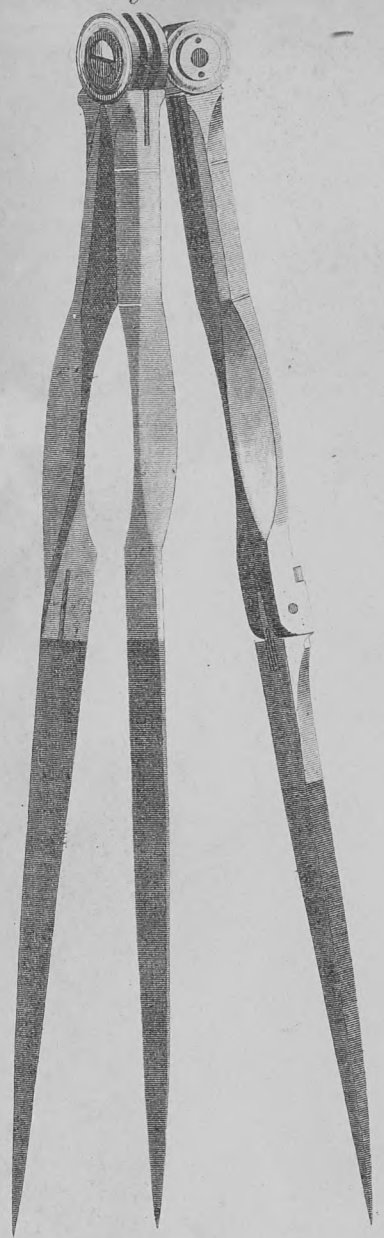


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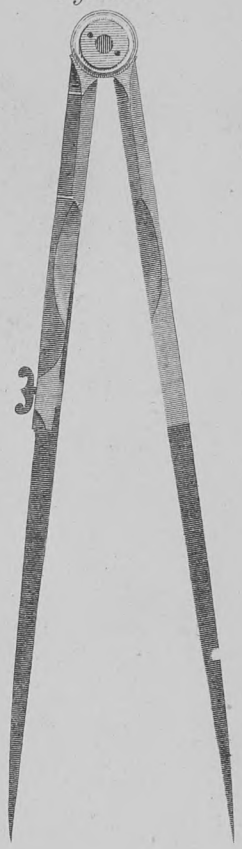


Fig. 10. N°3.



Fig. 10. N°2



Fig 10 N°1.

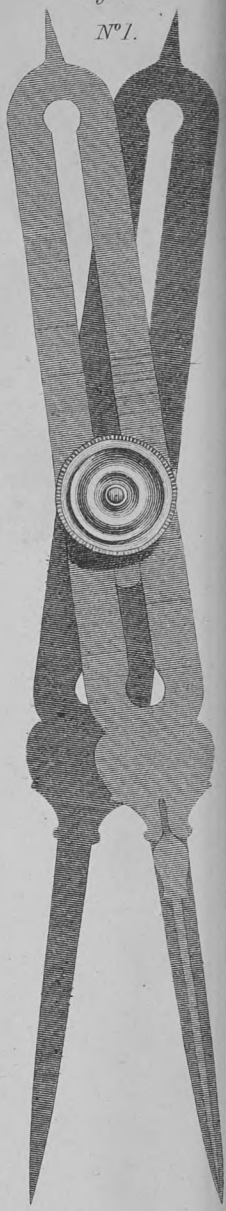


Fig. 12, N°2.



Fig. 12.

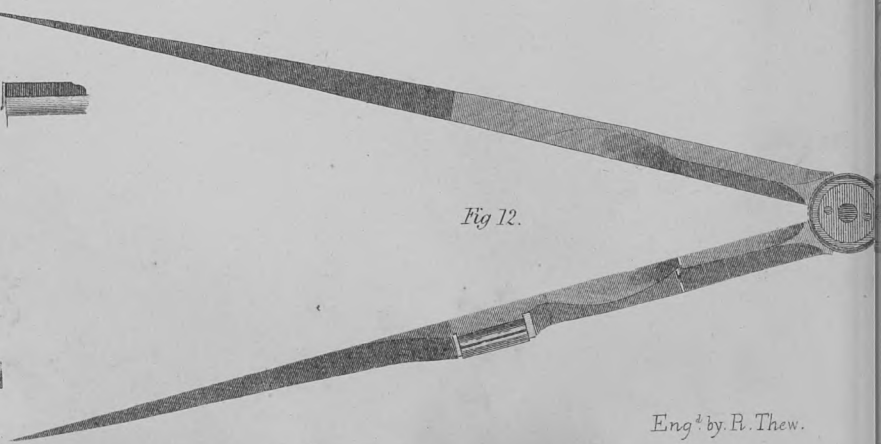
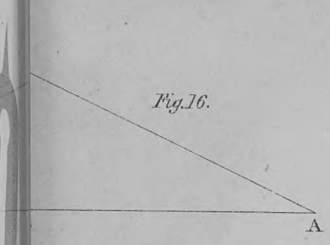


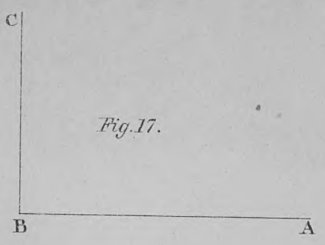
Fig. 12, N°1.

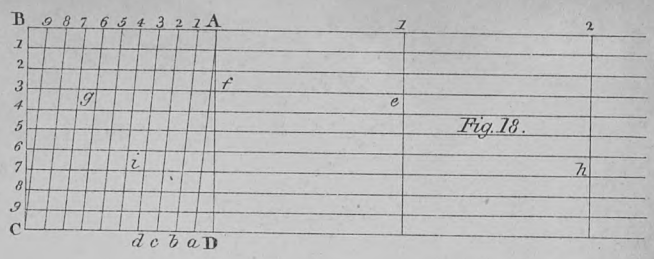


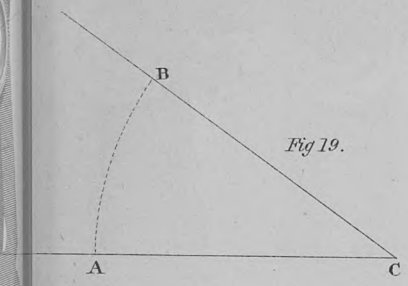
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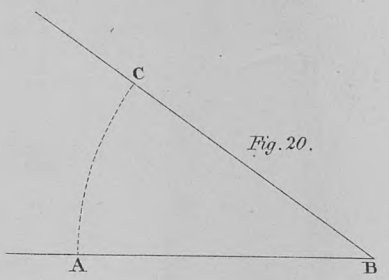
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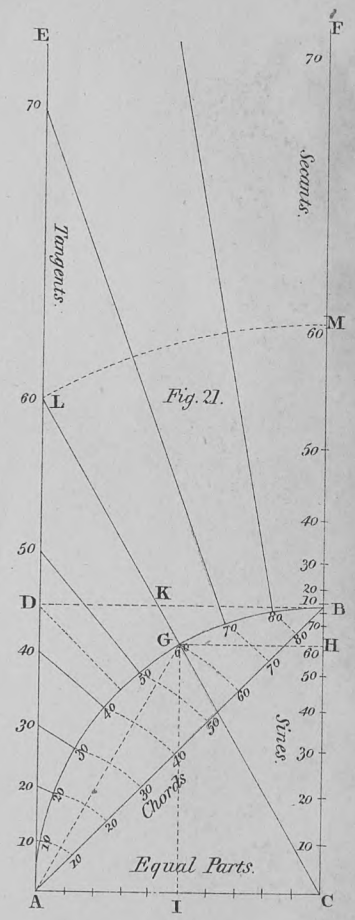

Fig. 16.
A

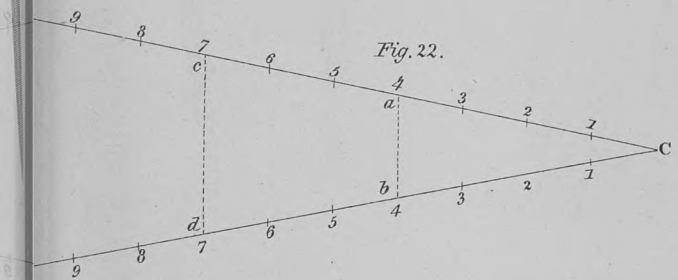

C
Fig. 17.
B
A

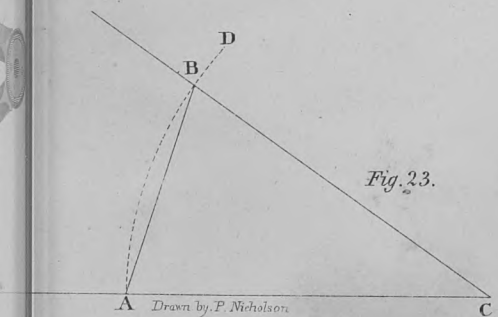

B 9 8 7 6 5 4 3 2 1 A
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Fig. 18.

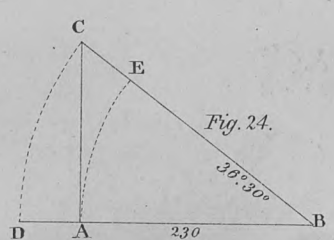

B
Fig 19.
A
C

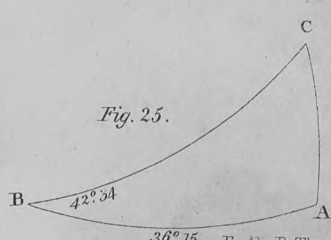

C
Fig. 20.
A
B

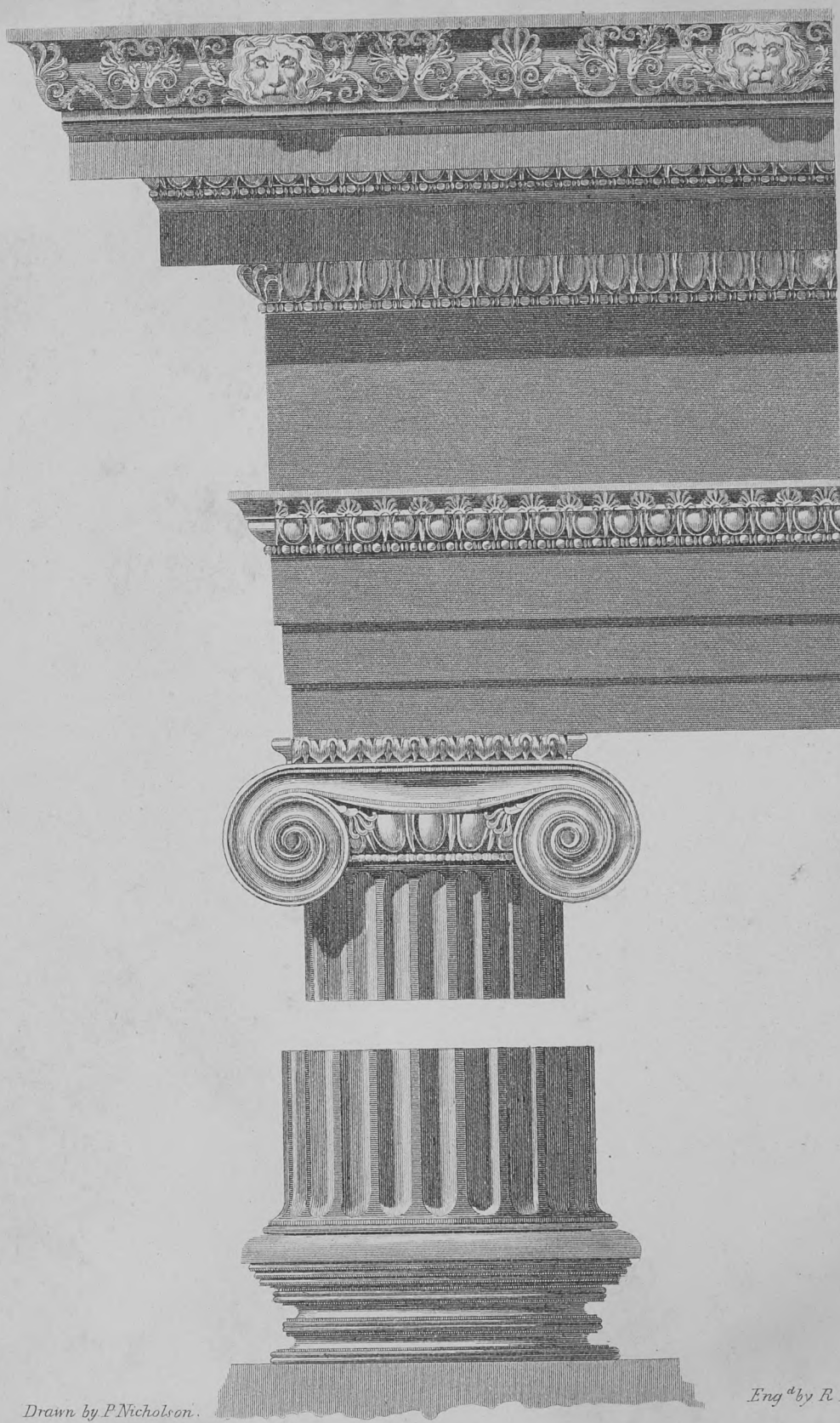

E
F
70
Tangents.
Secants.
M
60
L
Fig. 21.
50
40
30
20
10
D
K
B
G
H
Sines.
Chords
Equal Parts.
A
I
C


9 8 7 6 5 4 3 2 1
c
a
b
d
C
Fig. 22.


D
B
Fig. 23.
A
C
Drawn by P. Nicholson.


C
E
Fig. 24.
38°30'
D
A
230
B


C
Fig. 25.
B
42°54
A
36°15
Engd by R. Thew.

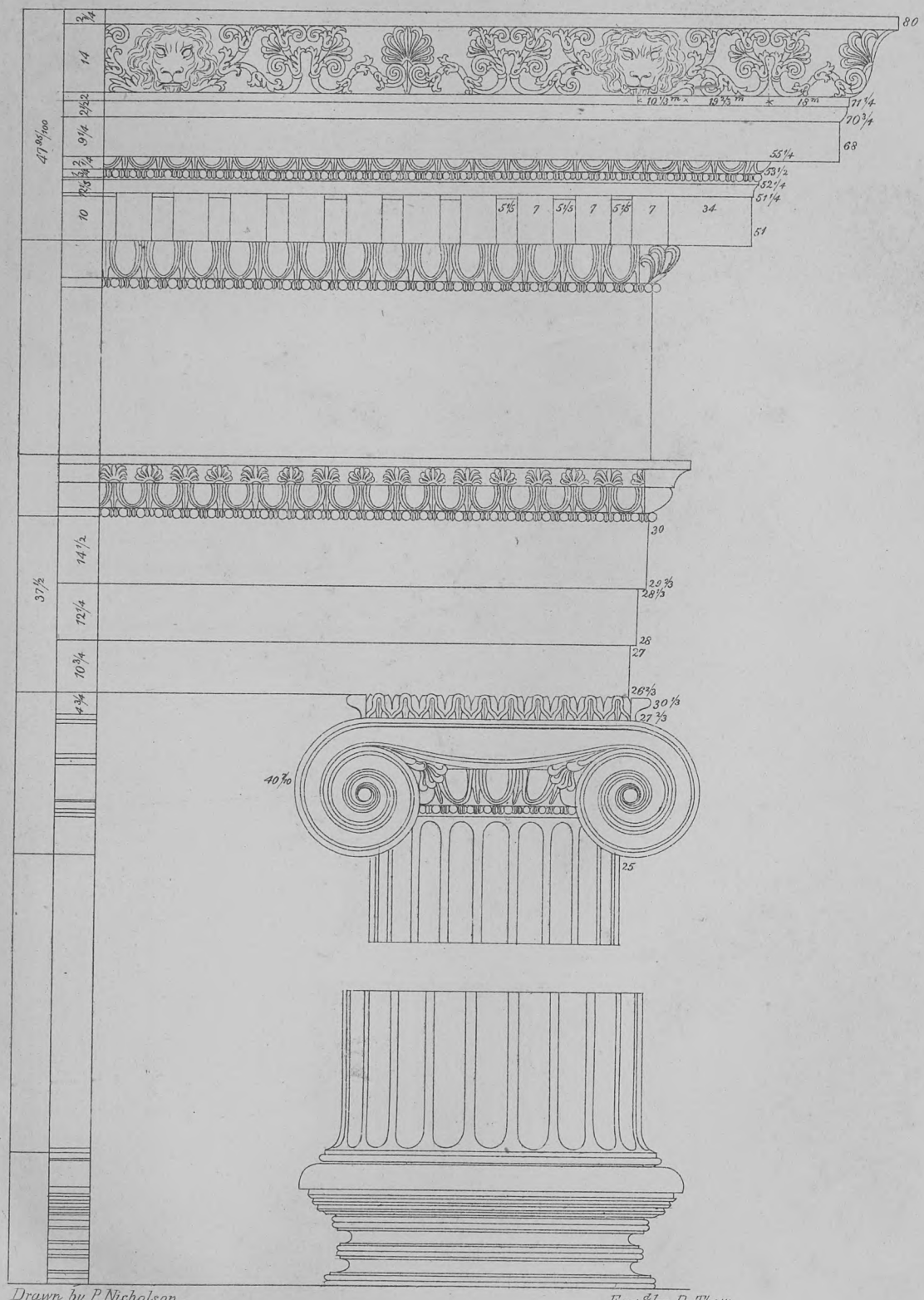


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Eng^d by R Thew.

IONIC ORDER.

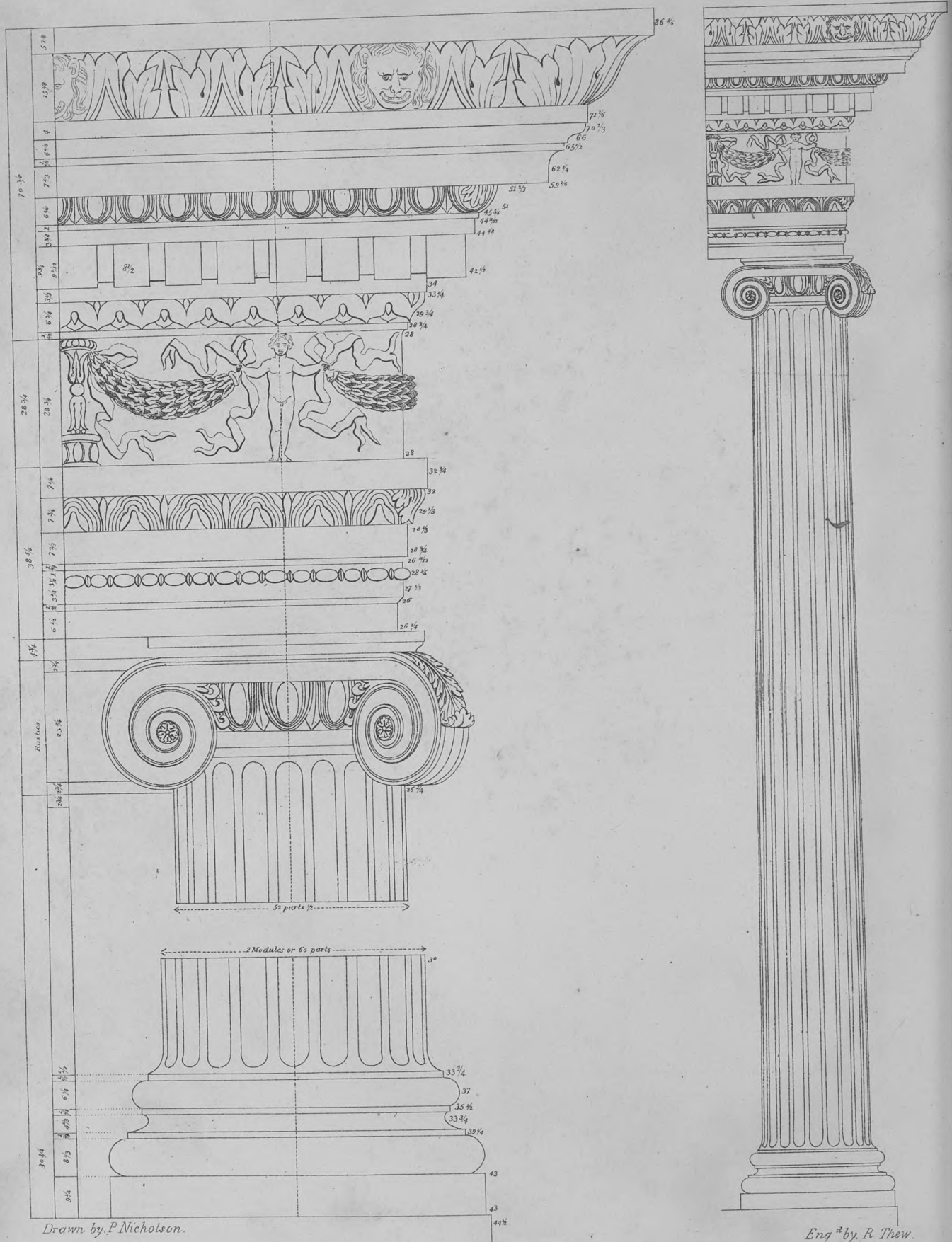
PLATE II.



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IONIC ORDER PLATE III.



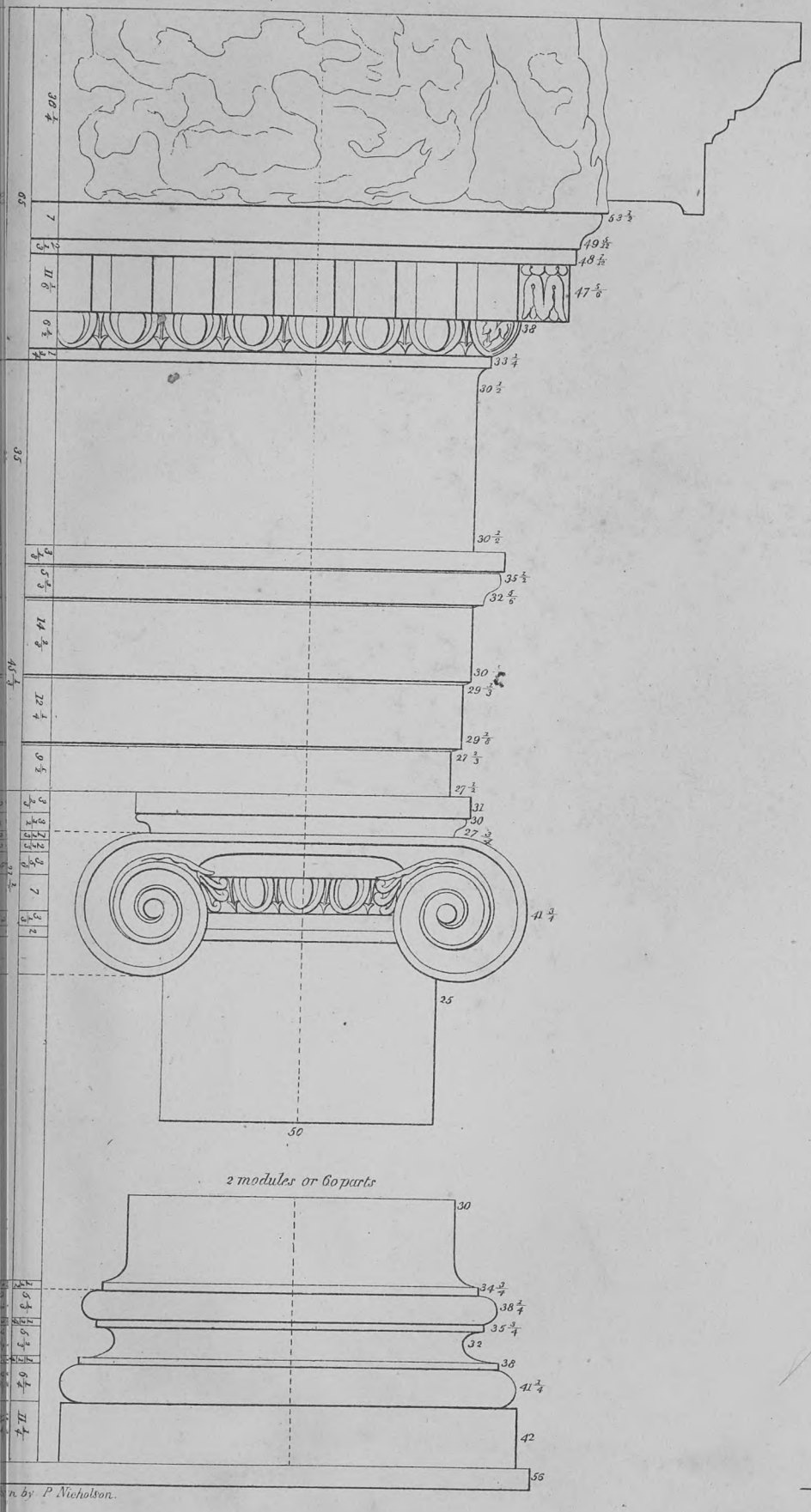
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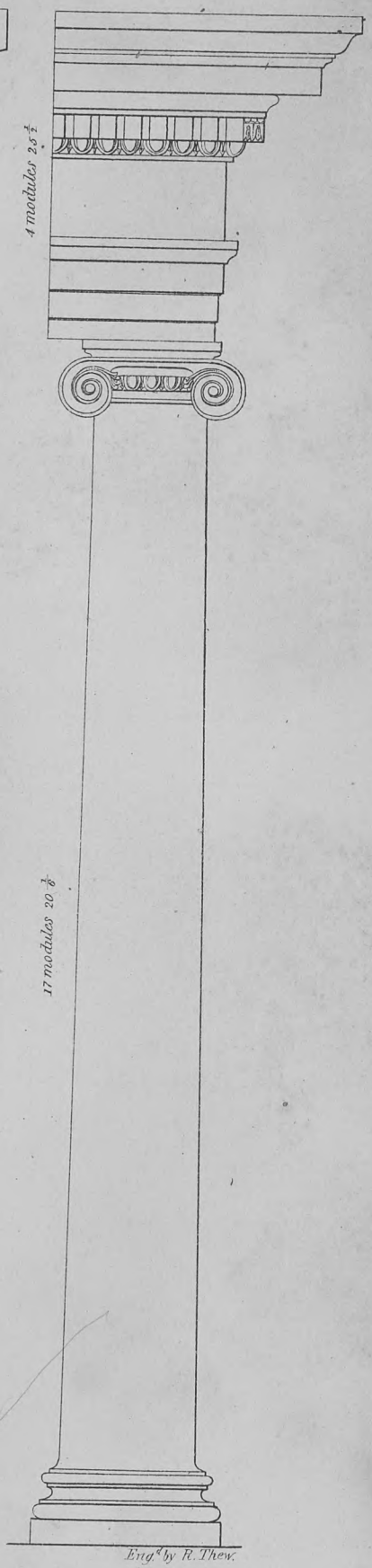
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IONIC ORDER.

FROM THE THEATRE OF MARCELLUS AT ROME.

PLATE IV

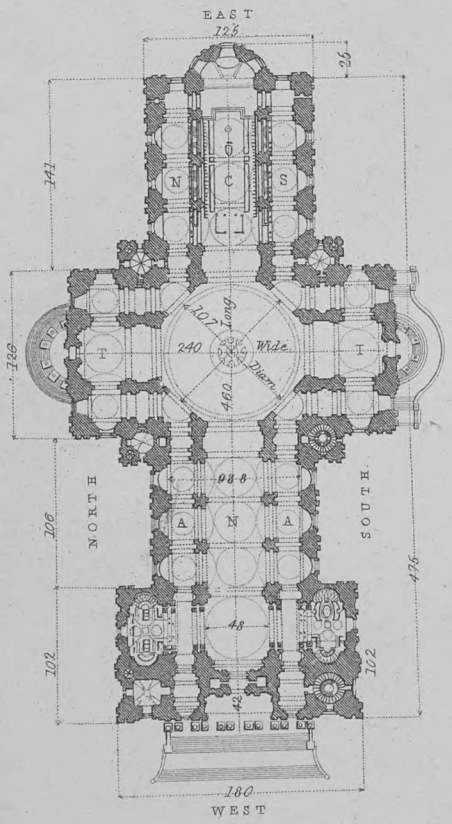




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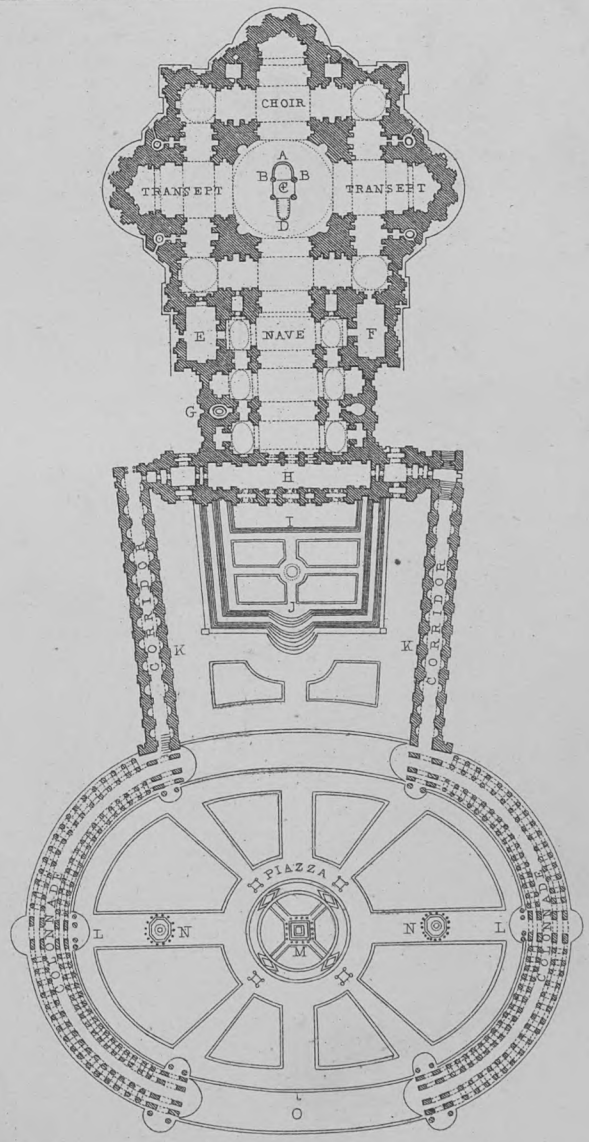
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GENERAL PLAN OF St PAULS IN LONDON AND St PETERS AT ROME.



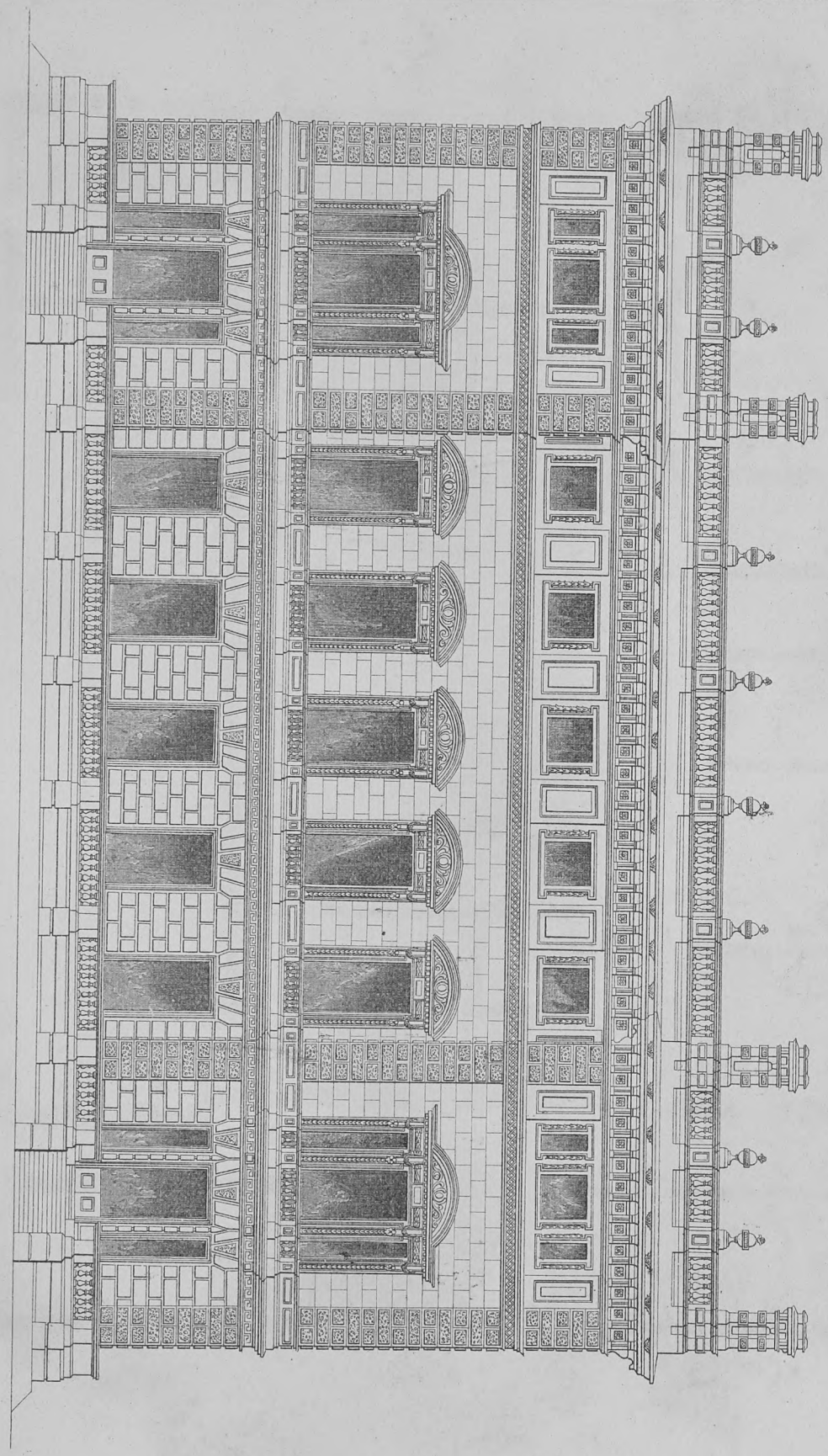
Scale of 10 50 100 150 200 Feet

GENERAL PLAN OF St PAULS.



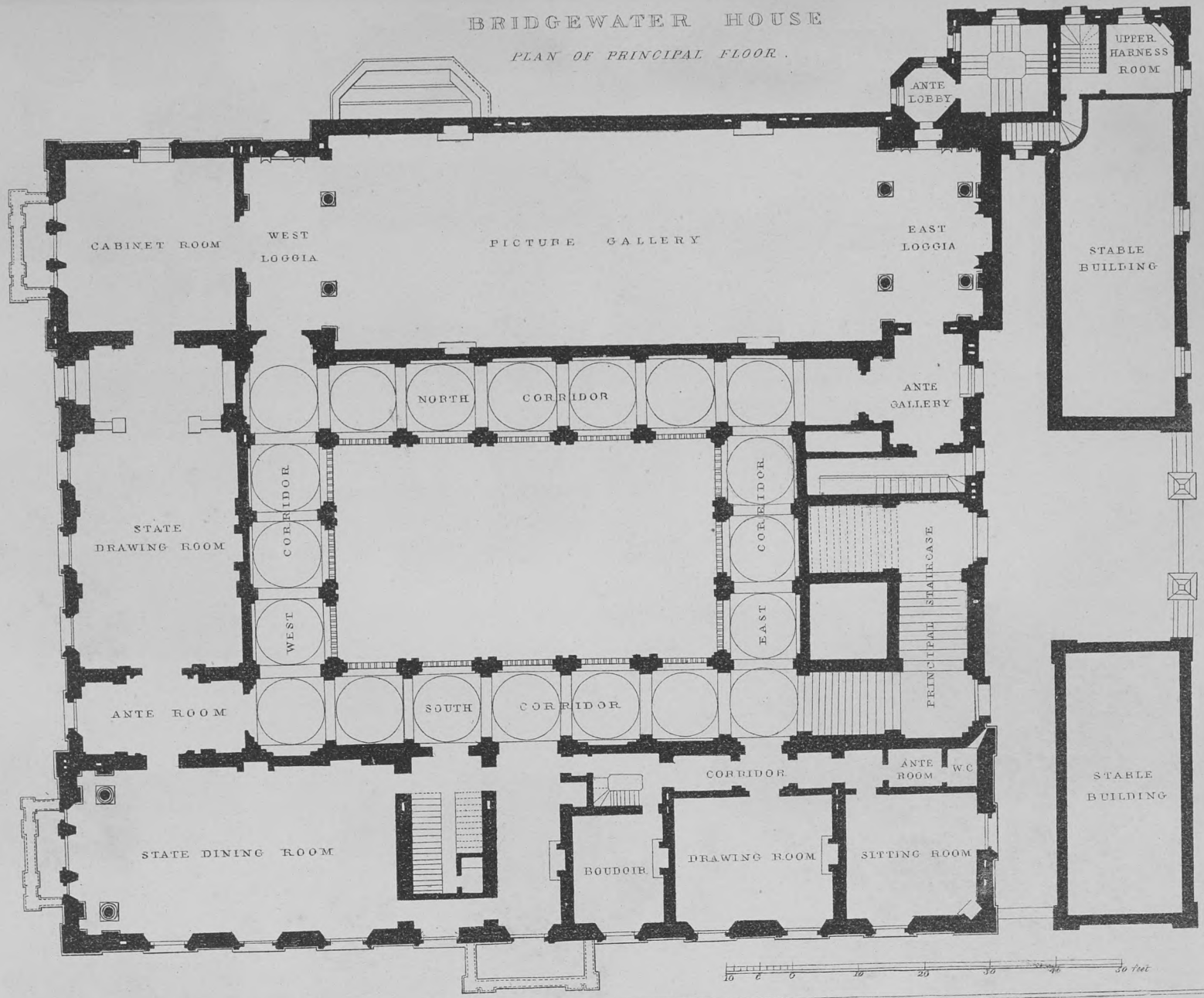
GENERAL PLAN OF St PETERS.

R. Thew sc



BRIDGEWATER HOUSE

PLAN OF PRINCIPAL FLOOR.



C.Barry.

R. Thom.

54 – VOL. 2

Fig. 6.



Fig. 5.

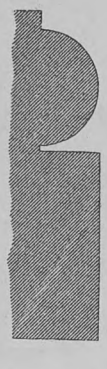


Fig. 4.

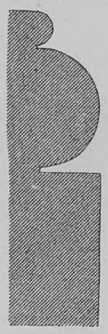


Fig. 3.

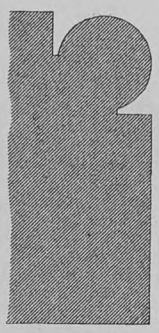


Fig. 2.

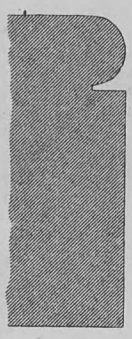


Fig. 1.



Fig 10.

Fig. 13.

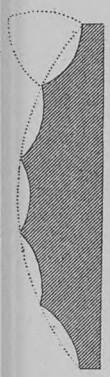


Fig. 12.



Fig 11





Fig. 9



Fig. 8.



Fig. 7.



Fig. 17.

Fig. 19.

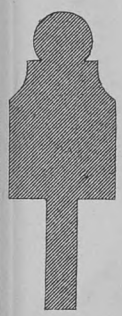
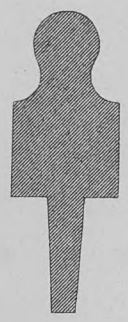


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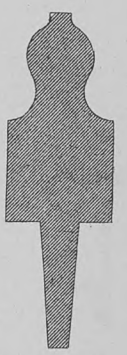


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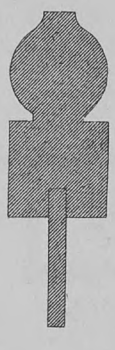


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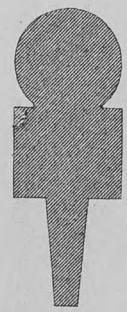


Fig 14

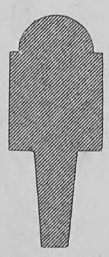


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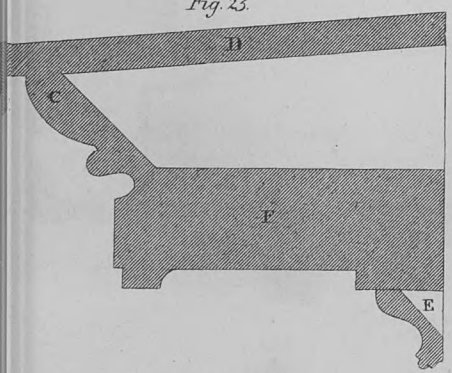


Fig. 22.



Fig. 21.

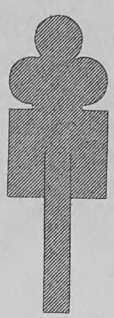
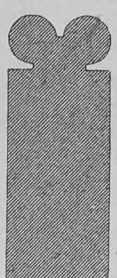


Fig. 20.



Drawn by M A Nicholson

Engd by R Thew

Fig. 24.

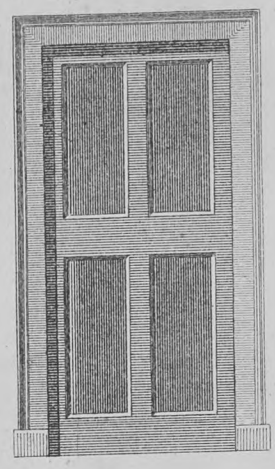


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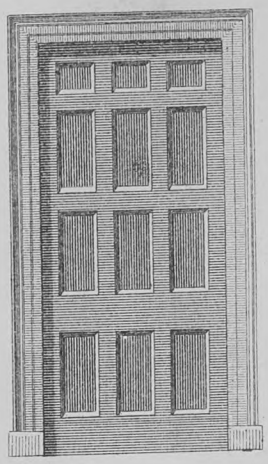


Fig 26

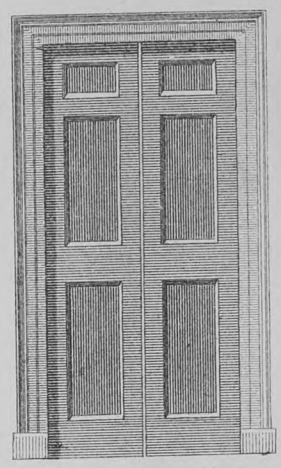


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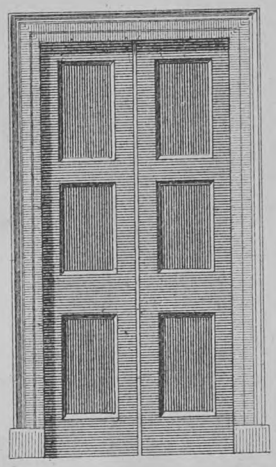


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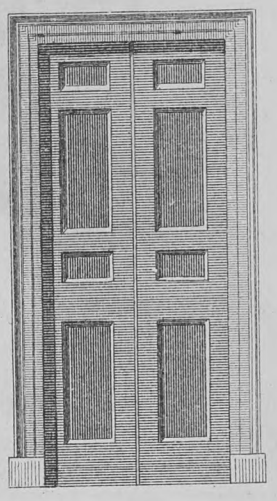


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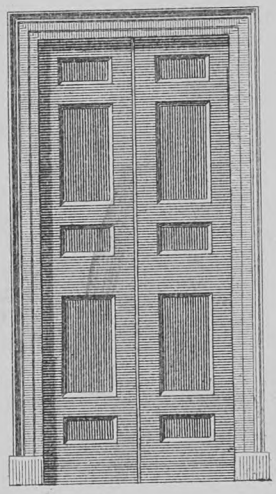


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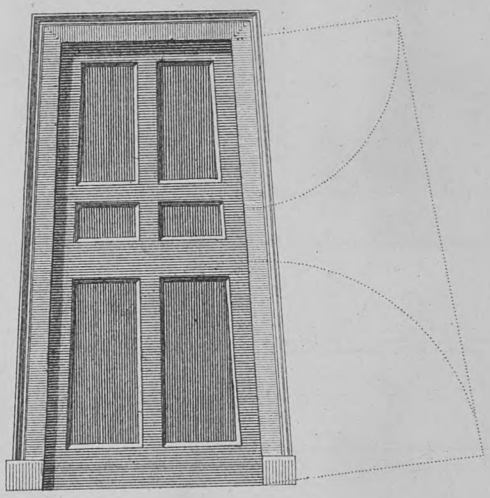


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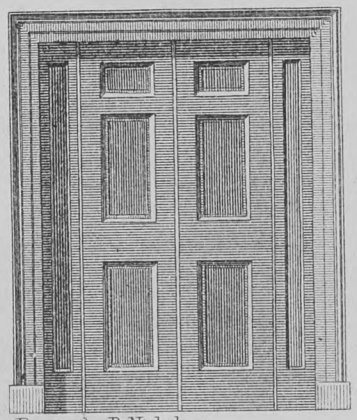


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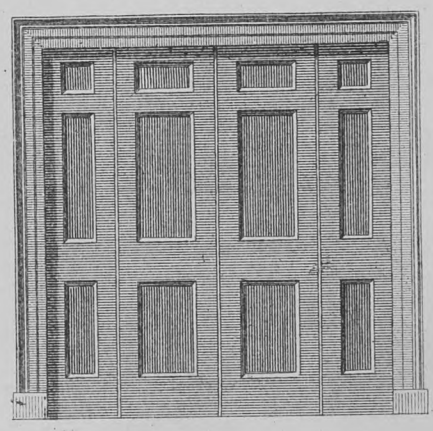
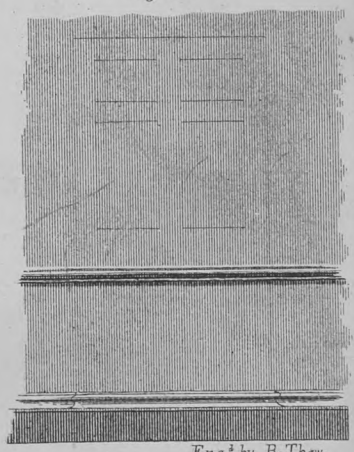


Fig. 33.



Drawn. by P. Nicholson.

Engd by R. Thew.

Fig. 34.

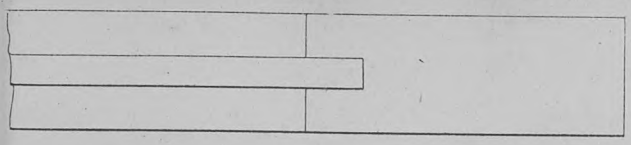


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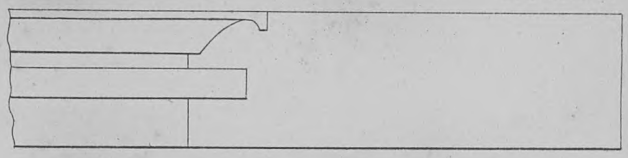


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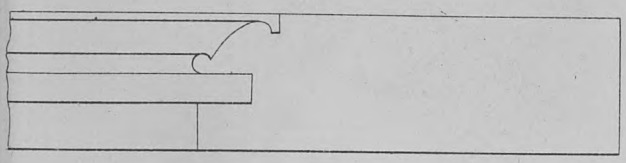


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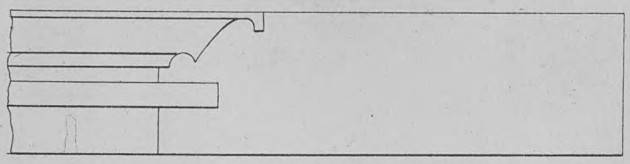


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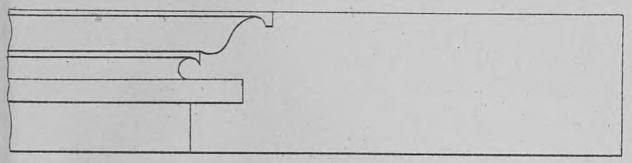


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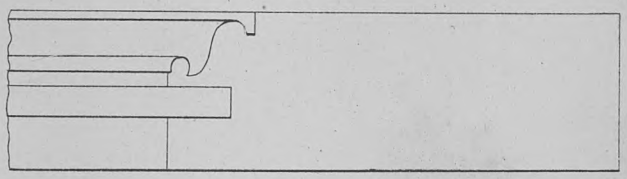


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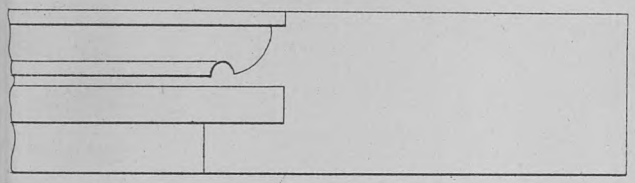


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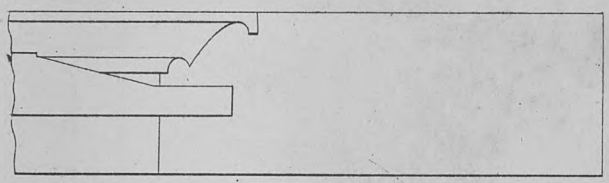


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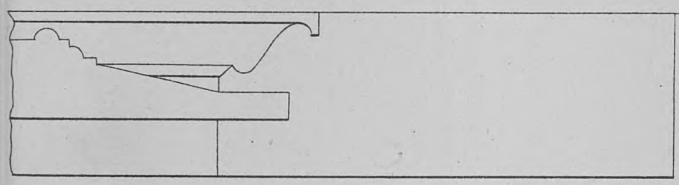


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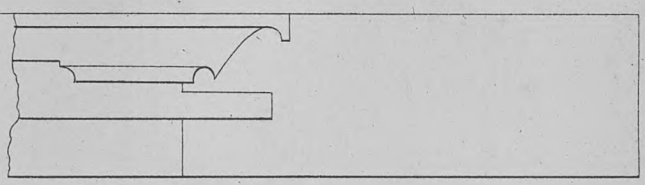


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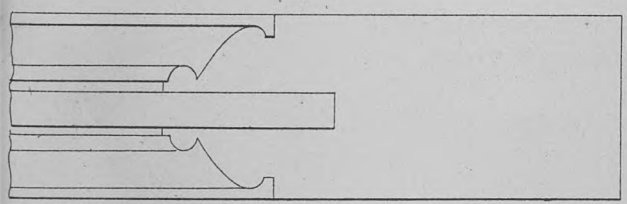


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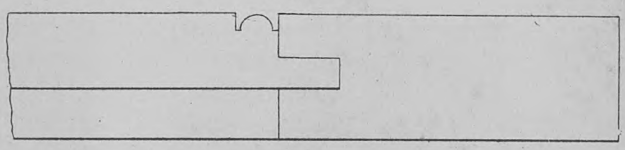


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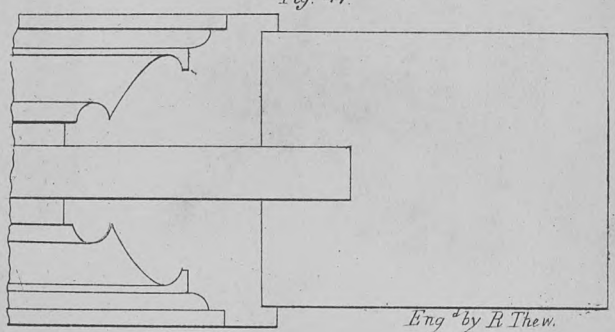
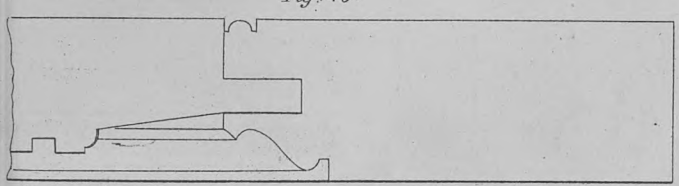


Fig. 46.



Designed by P.N.
Drawn by M.A Nicholson.

Eng^d by R Thew.

Fig. 48.

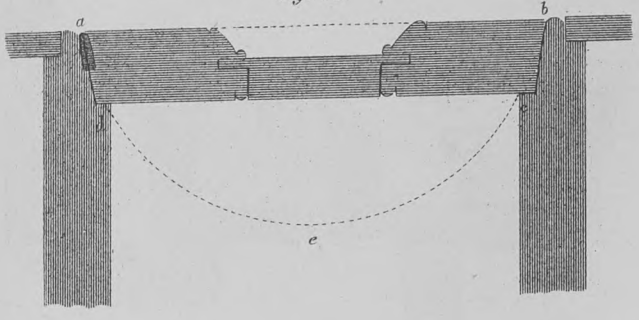


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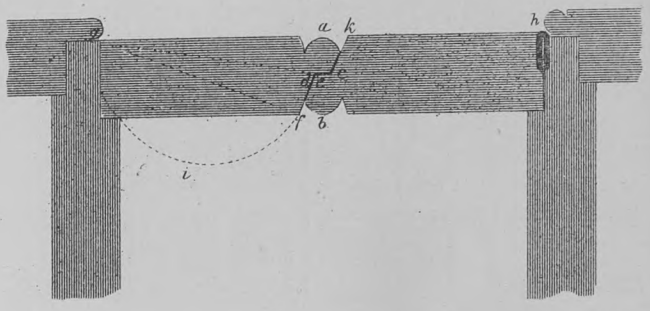


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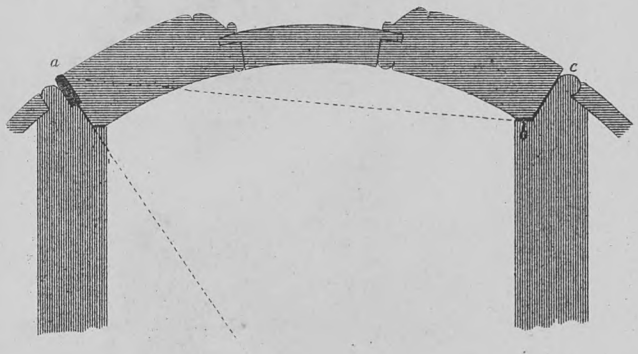


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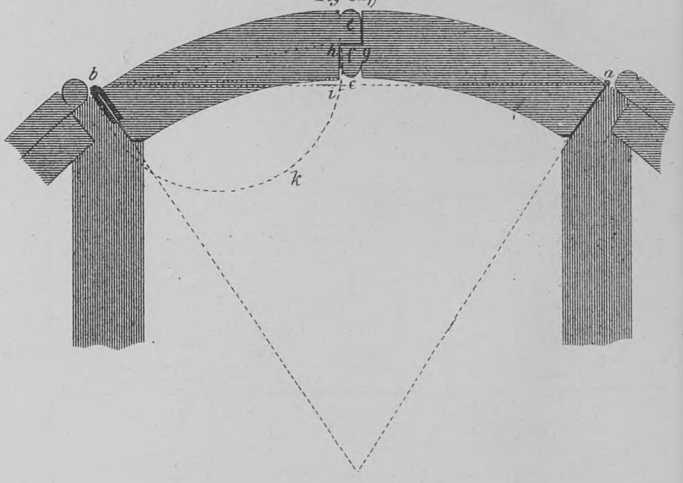


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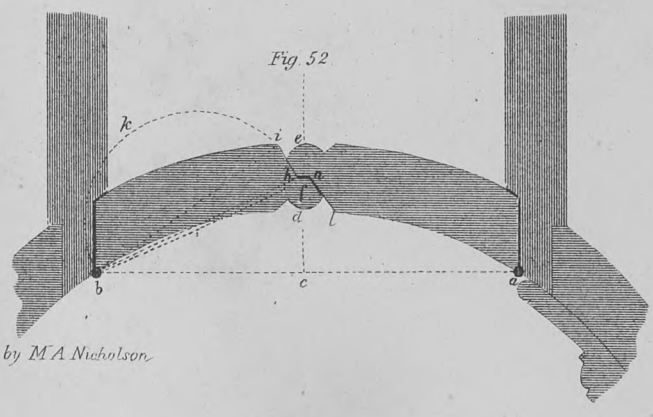
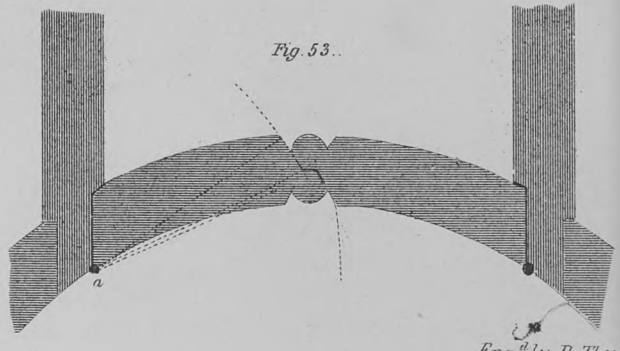


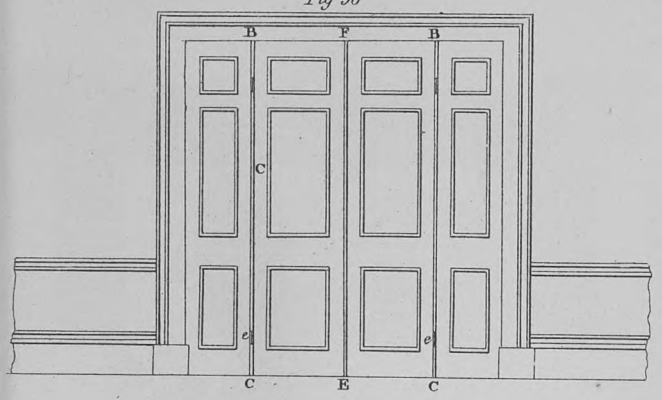
Fig. 53.



Drawn by M A Nicholson.

Eng.d by P. Thew

Fig 58



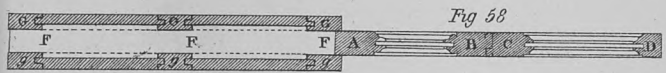


Fig 58

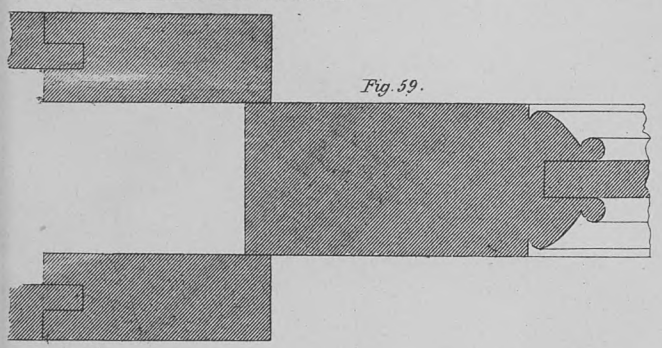


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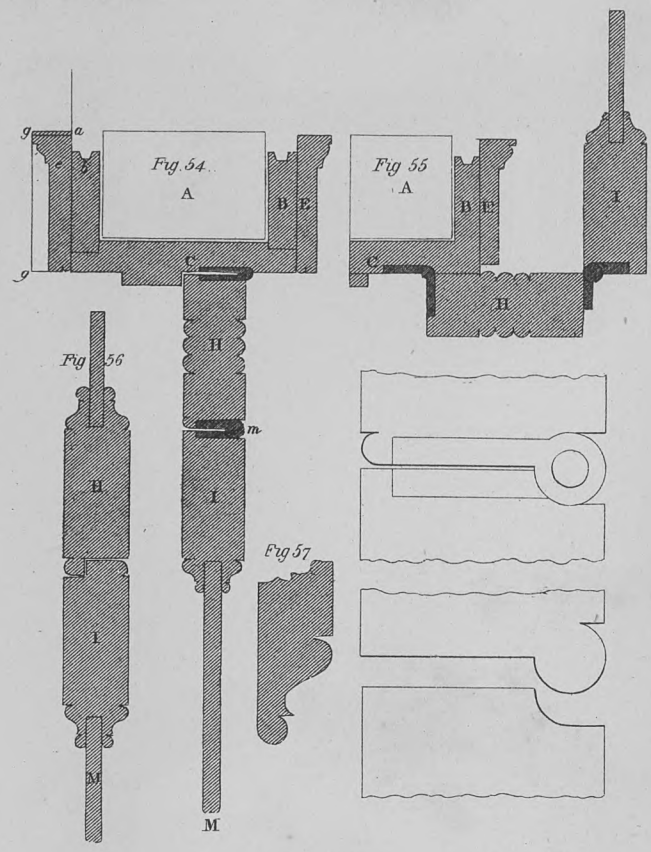
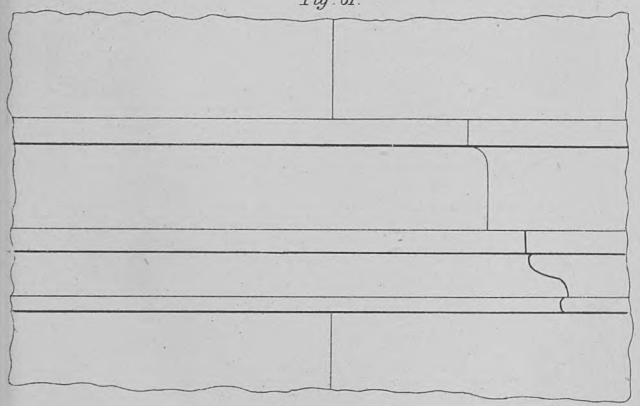
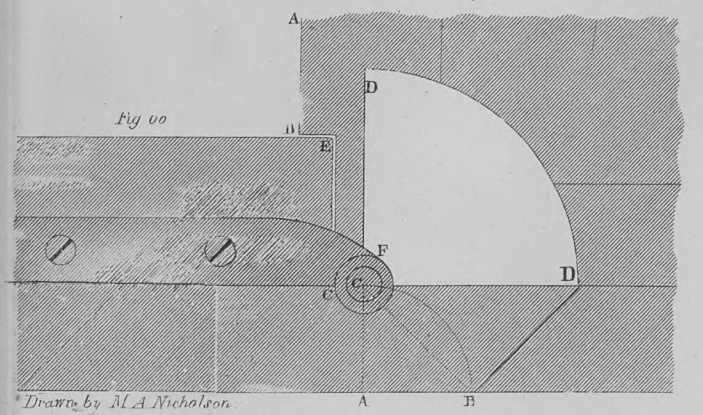
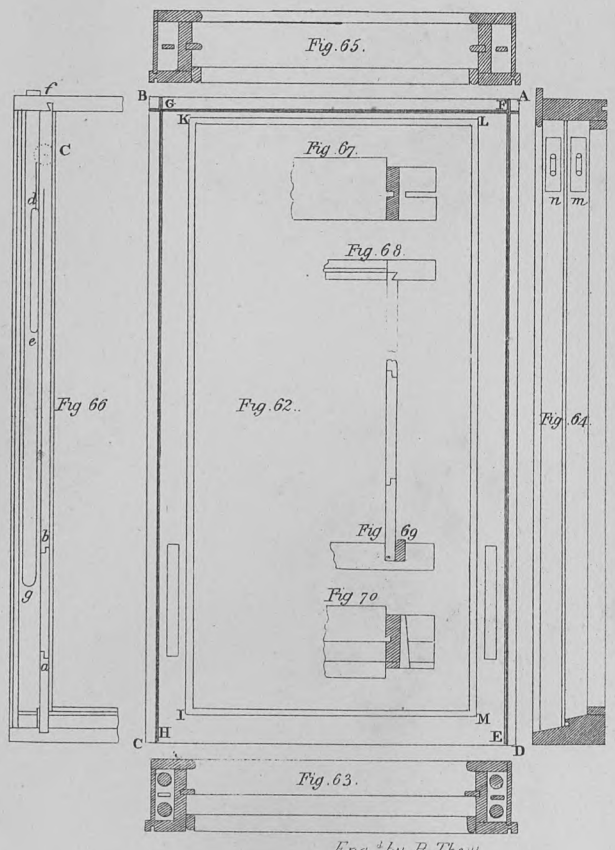


Fig. 61.





Drawn by M A Nicholson.



Eng^d by R. Thew.

PLATE VI.

Fig. 75.

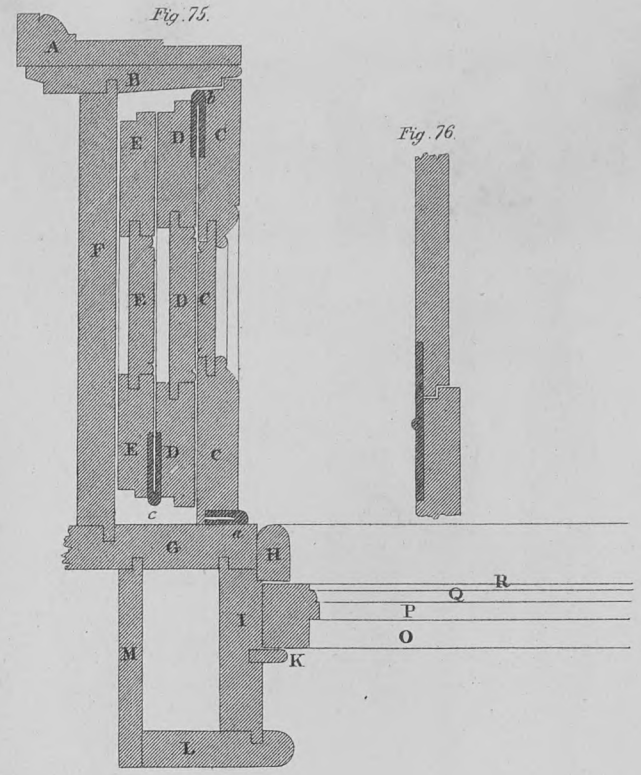


Fig. 76.

Fig. 72.

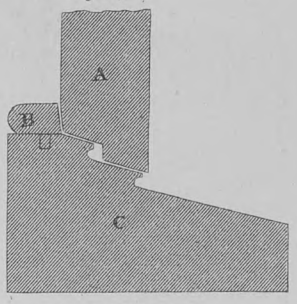


Fig. 71.

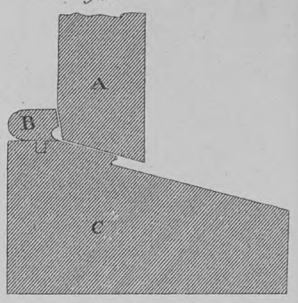


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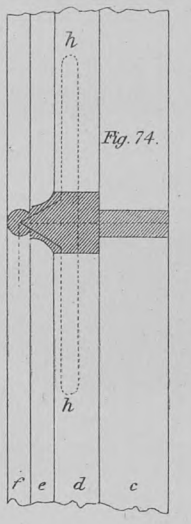


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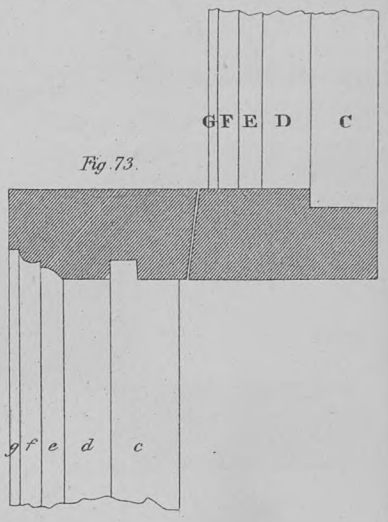
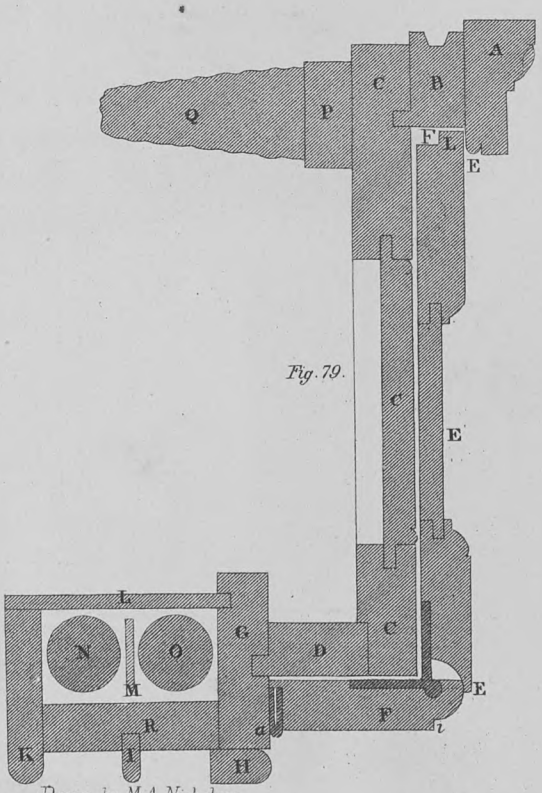


Fig. 79.



Drawn. by M.A. Nicholson.

Fig. 77.

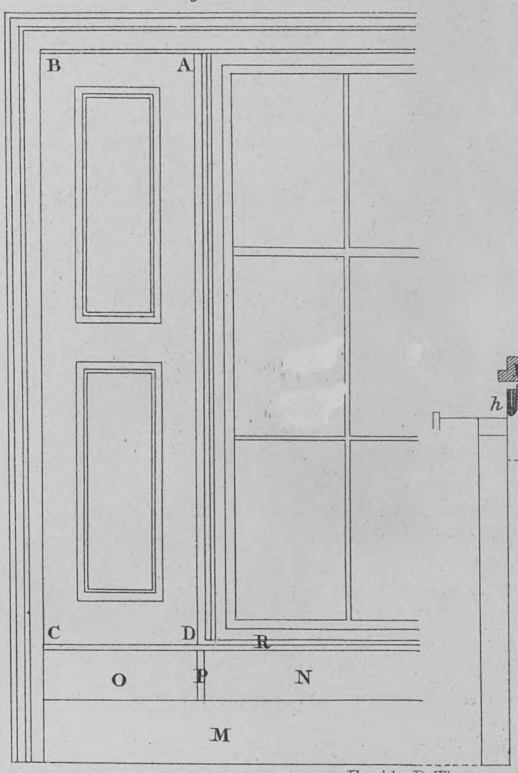
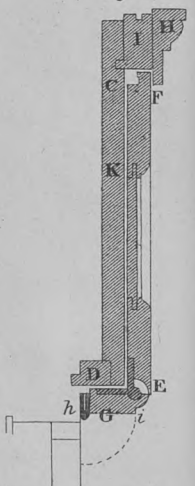


Fig. 78.



Engd. by R. Thew.

Fig. 80.

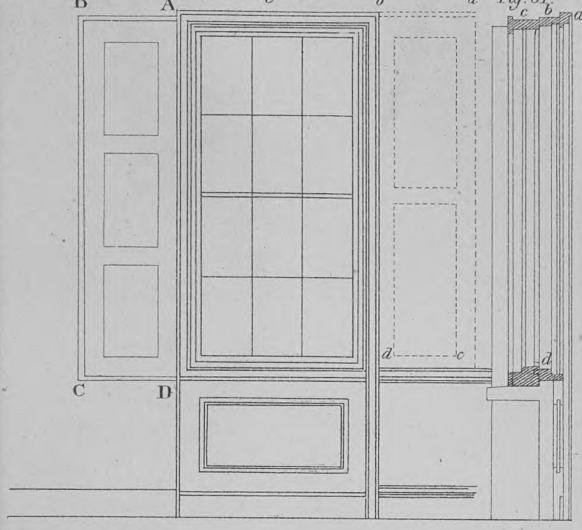


Fig. 81.

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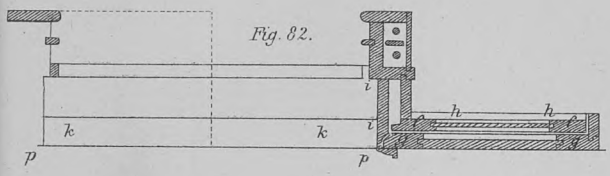


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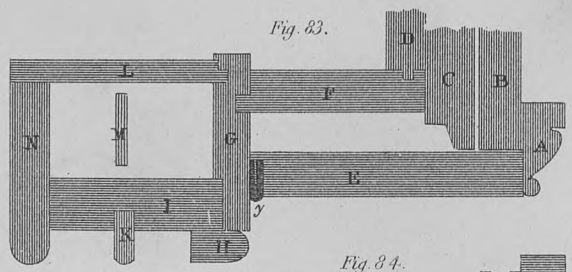


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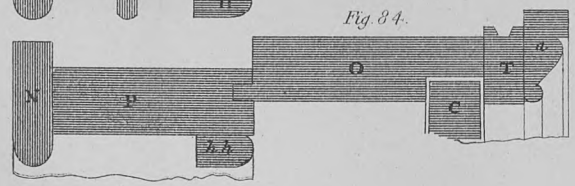


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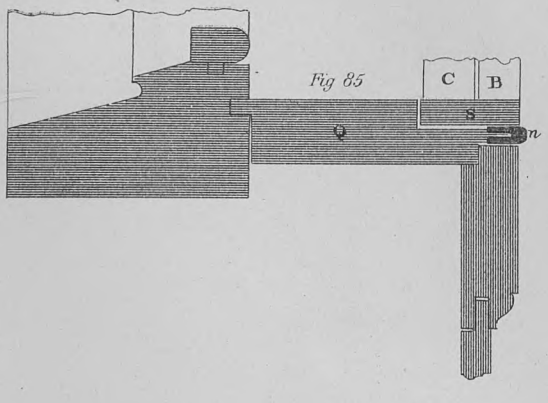


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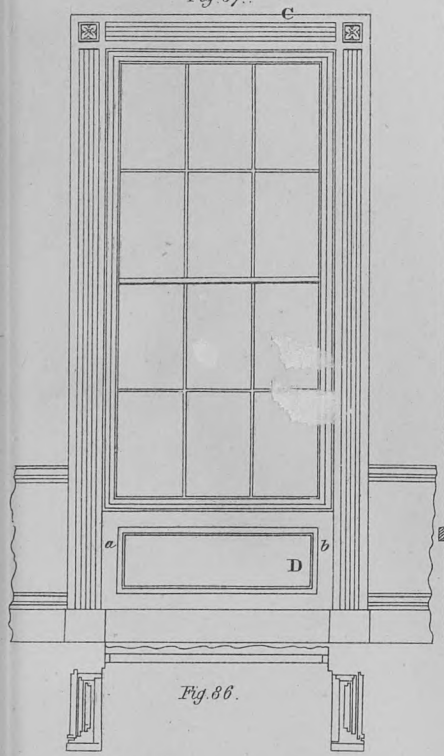


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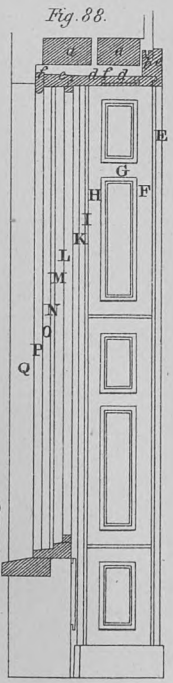


Fig. 86.

Fig. 89.

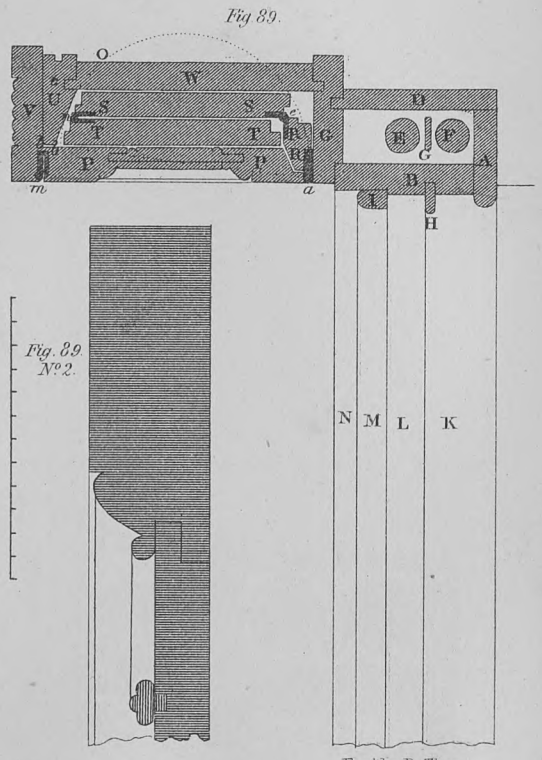


Fig. 89 Nº 2.

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Engt. by R. Thew.

Fig. 92.

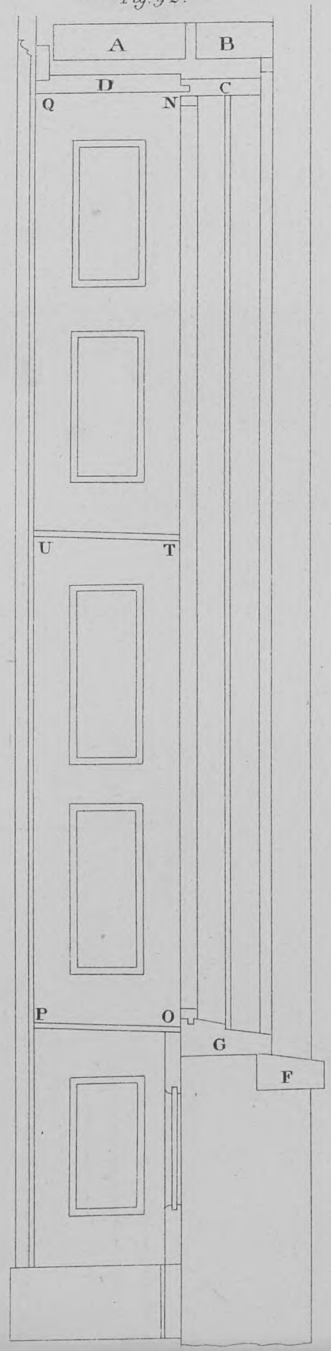


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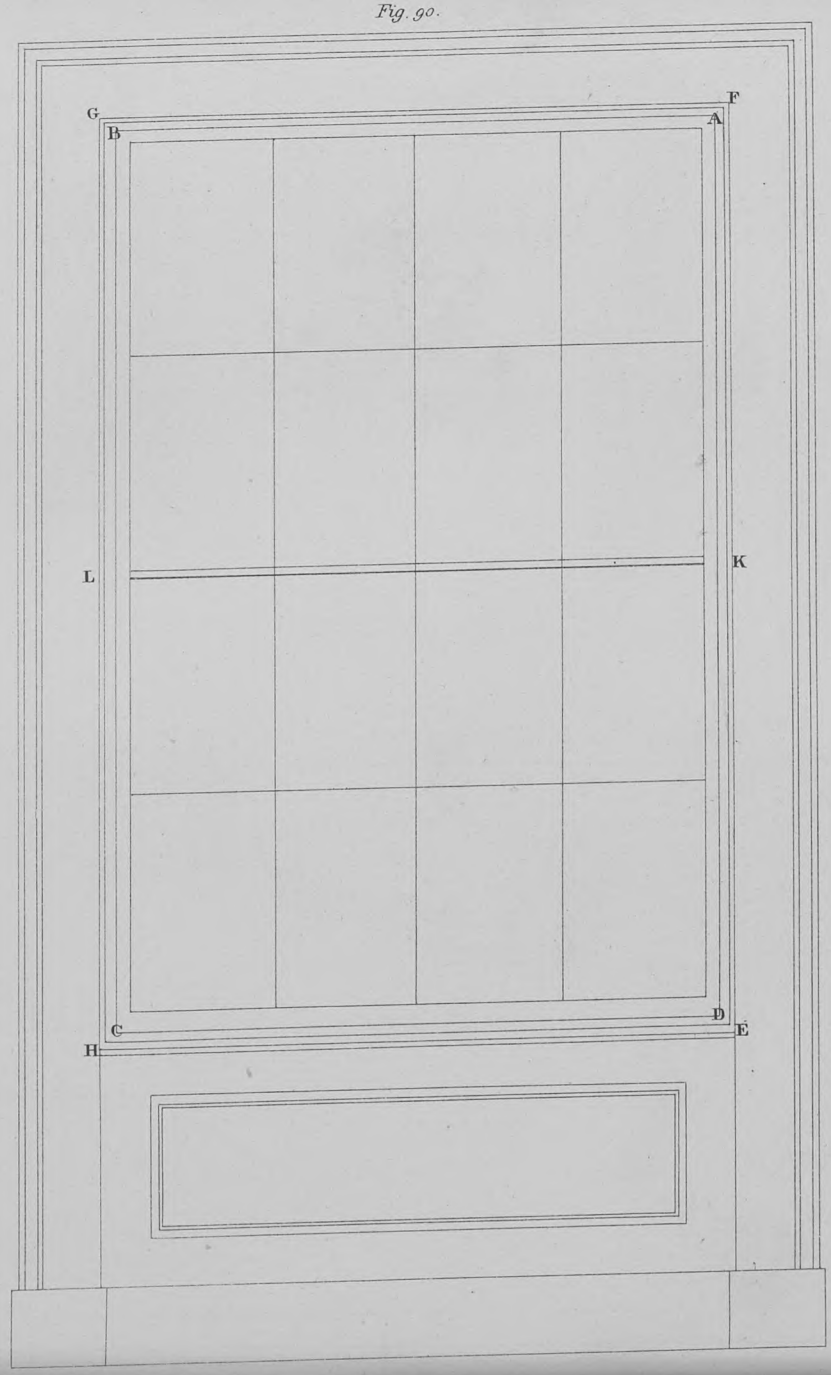
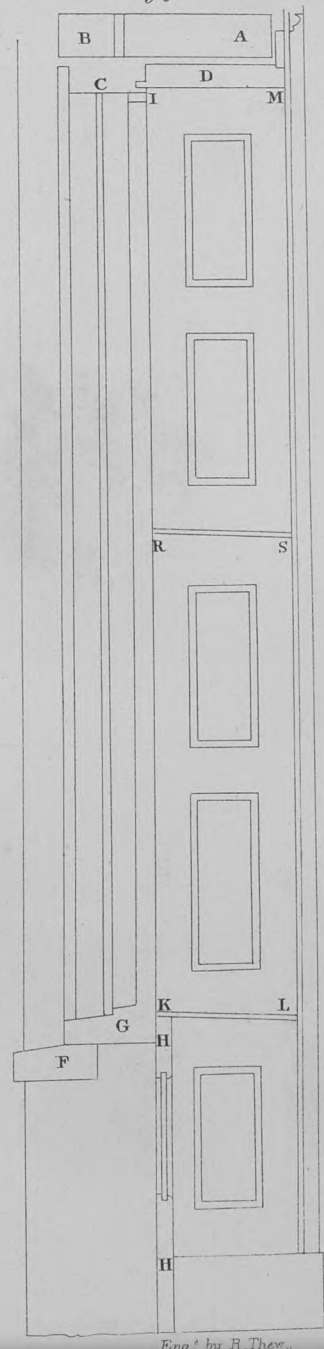


Fig. 91.



Eng.ᵈ by R. Thew.

70 - VOL. 2

Fig. 93



Fig. 94.

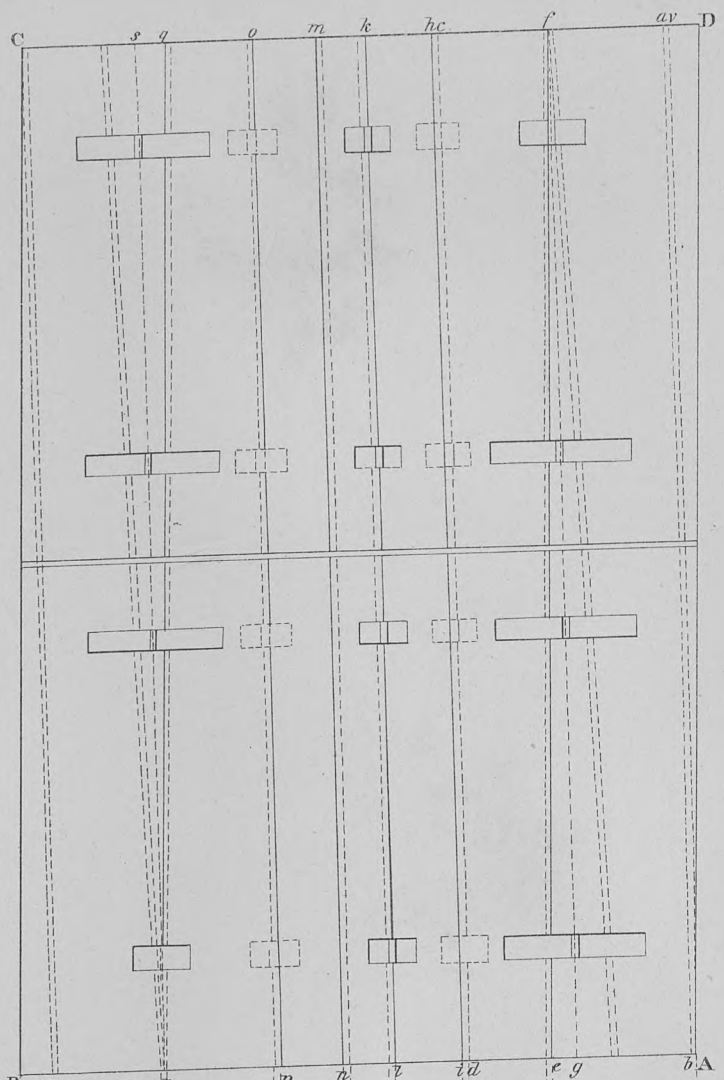
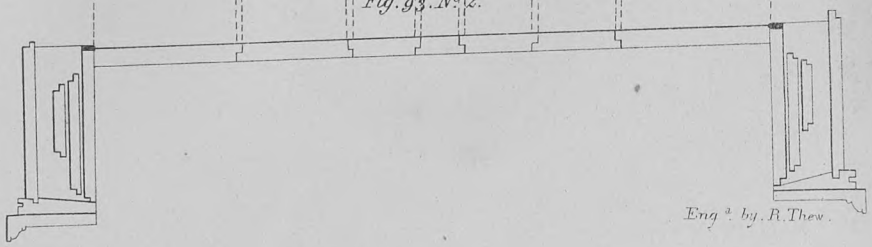
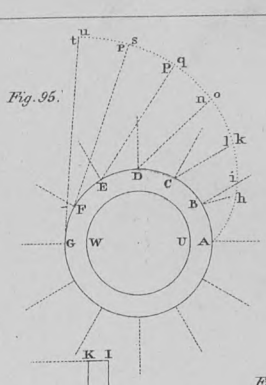


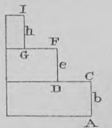
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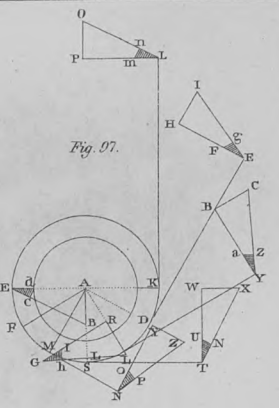


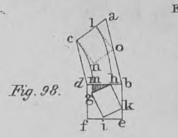
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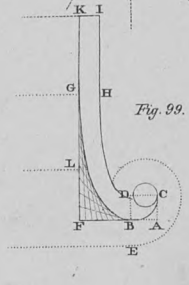
Engd by R. Thew.


Fig. 95.


Fig. 96.


Fig. 97.


Fig. 98.


Fig. 99.

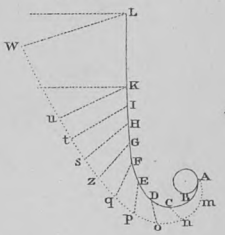

Fig. 100.


Fig. 101.

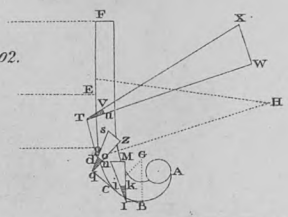

Fig. 102.

Fig. 105.

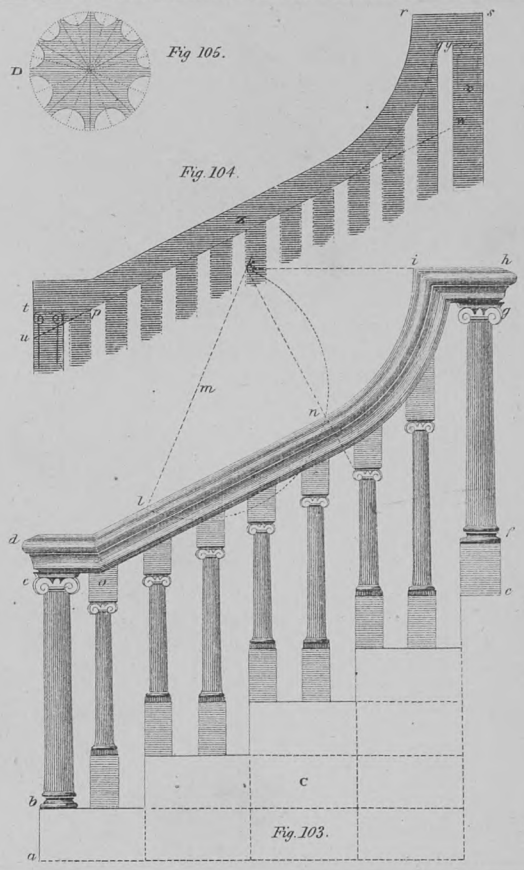

Fig. 104.

Fig. 103.

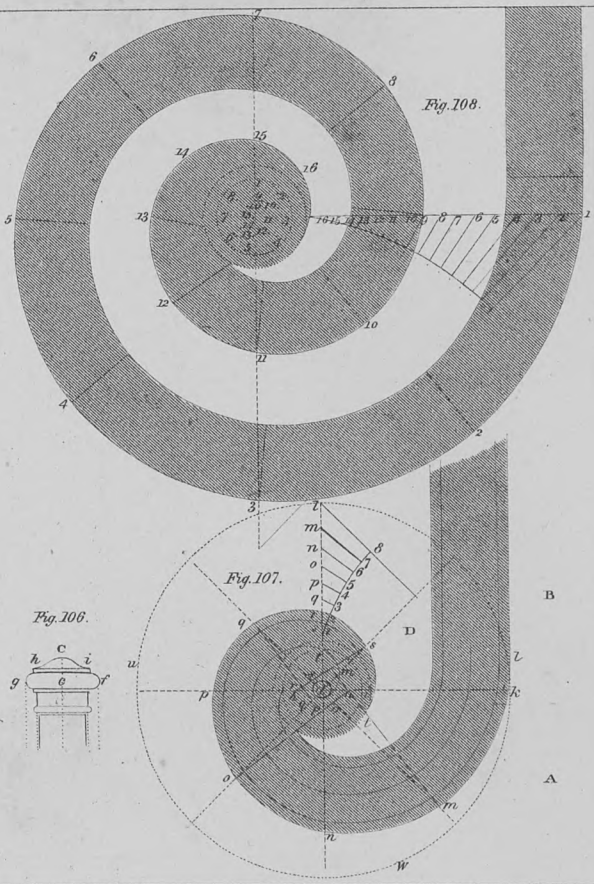

Fig. 108.

Fig. 107.

Fig. 106.

Fig. 115.

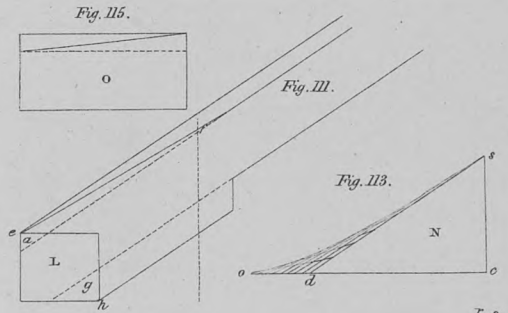

Fig. 111.

Fig. 113.

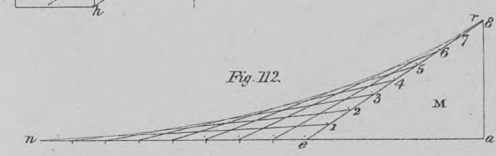

Fig. 112.

Fig. 110.

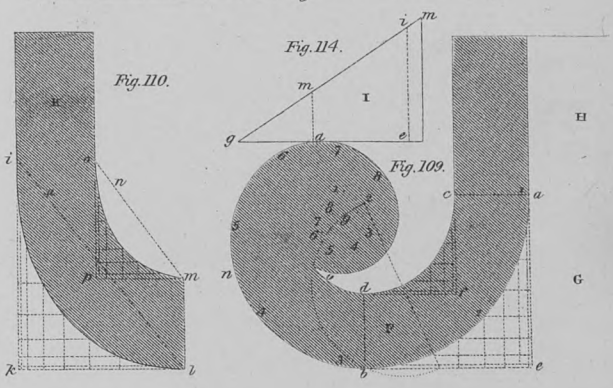
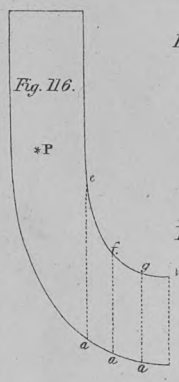
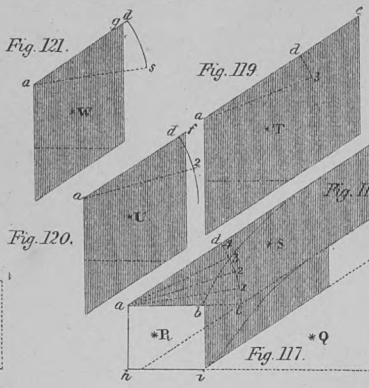
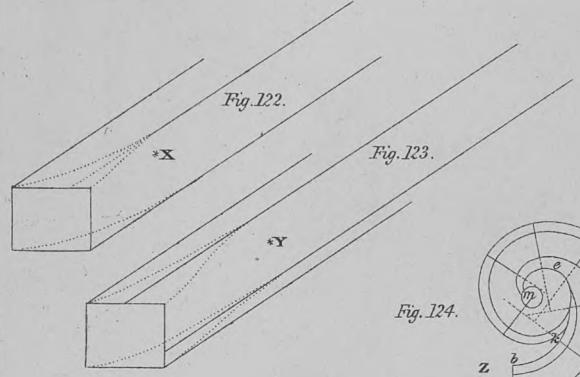

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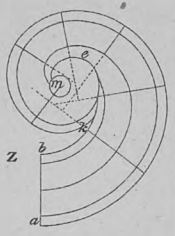
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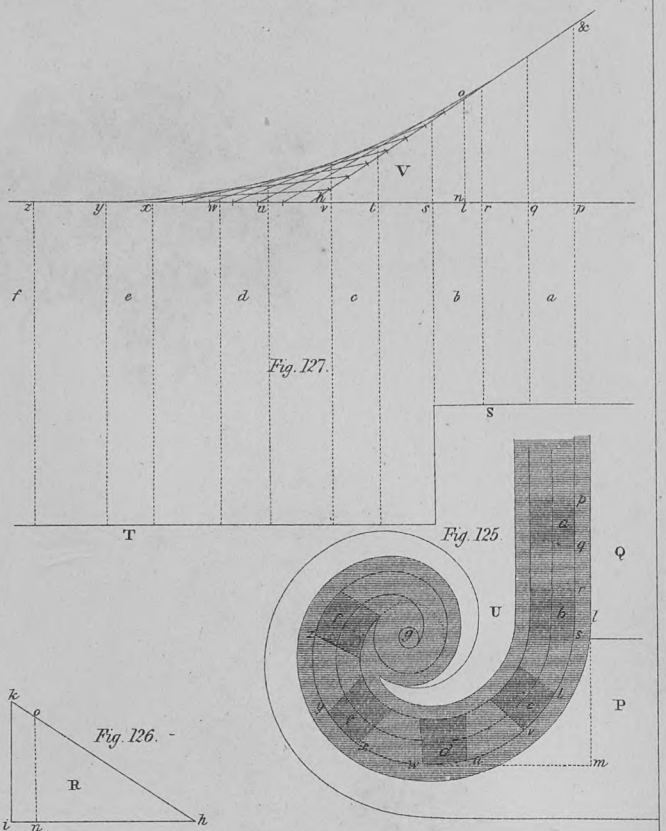
Drawn by P. Nicholson. R. Thew. Sc.

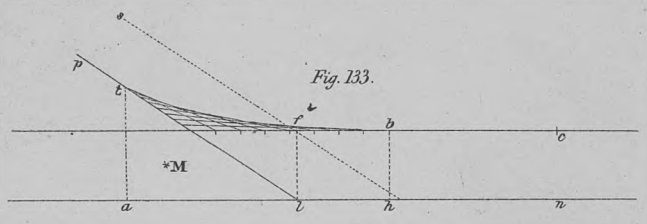


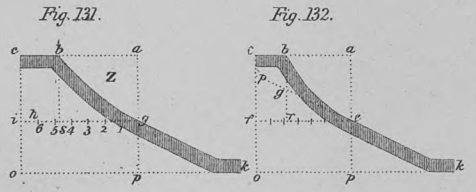


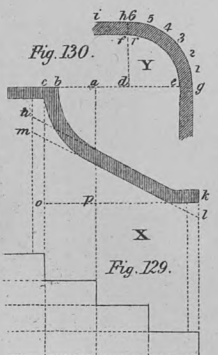


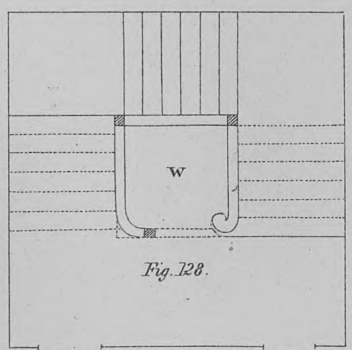


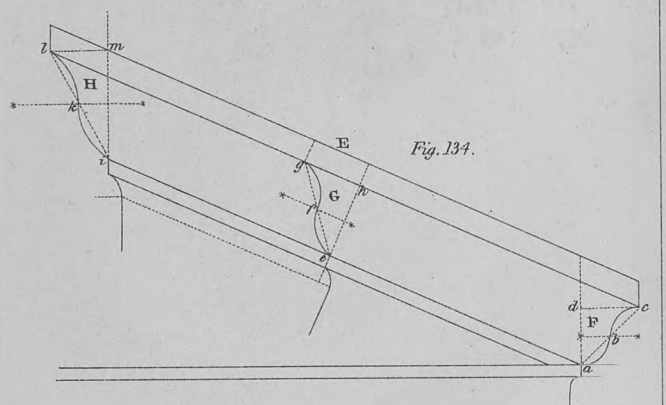


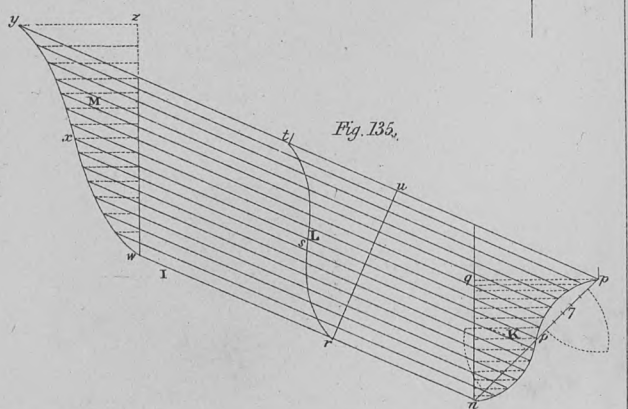












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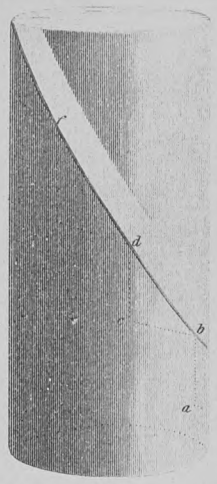


Fig. 11.

Fig. 139.

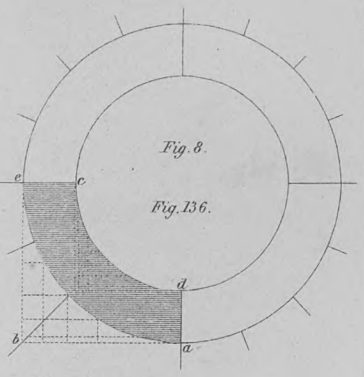


Fig. 8.

Fig. 136.

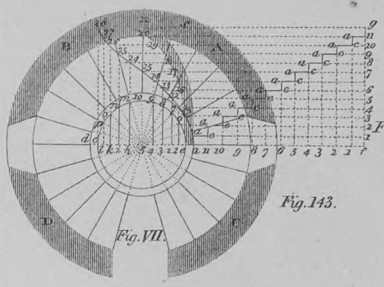


Fig. VII.

Fig. 143.

Fig. 142.

Fig. II.

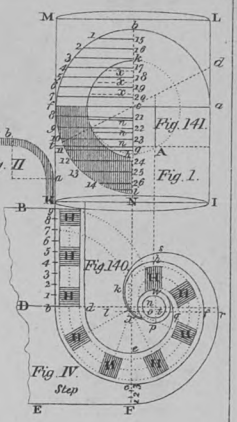


Fig. 141.

Fig. 1.

Fig. 140.

Fig. IV.

Step

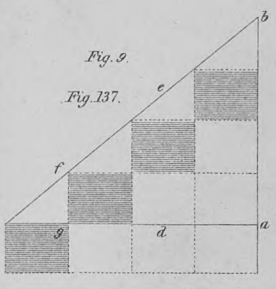


Fig. 9.

Fig. 137.

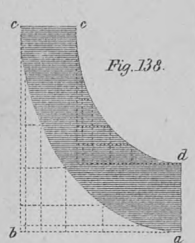


Fig. 10.

Fig. 138.

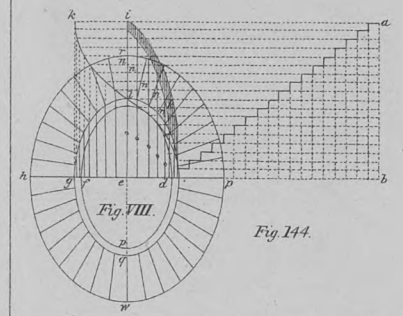


Fig. VIII.

Fig. 144.

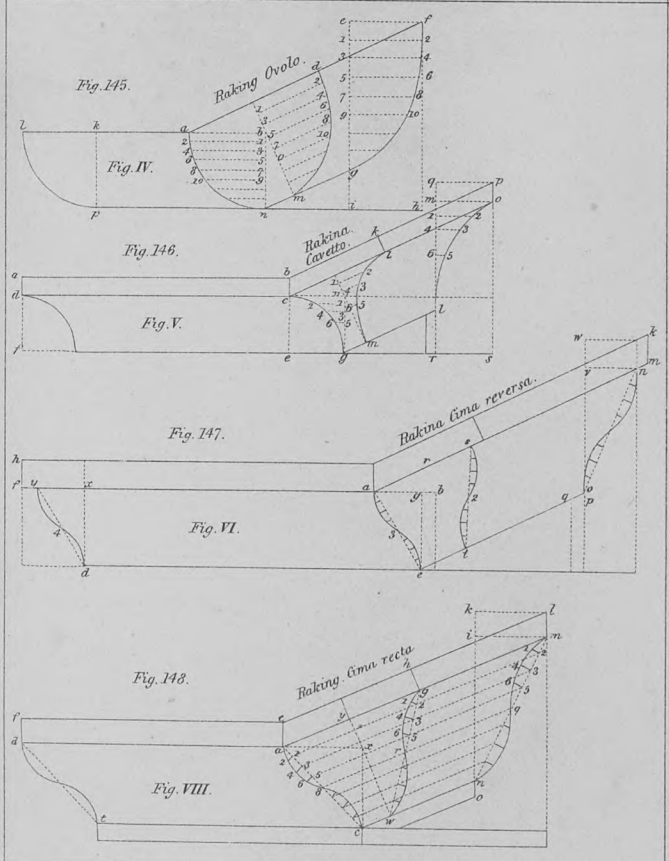


Fig. 145.

Raking Ovolo.

Fig. IV.

Fig. 146.

Raking Cavetto.

Fig. V.

Fig. 147.

Raking Cima reversa.

Fig. VI.

Fig. 148.

Raking Cima recta.

Fig. VIII.

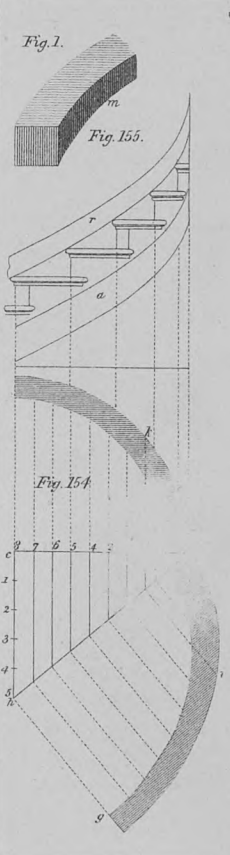


Fig. 1.

Fig. 155.

Fig. 154.



Fig. 156.

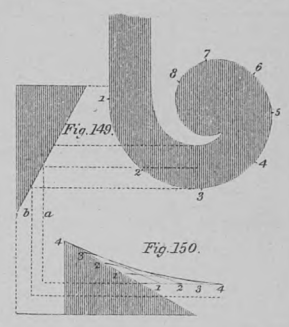


Fig. 149.

Fig. 150.

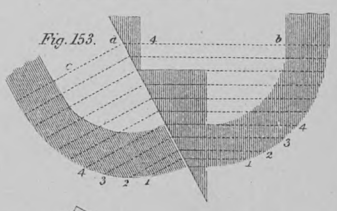


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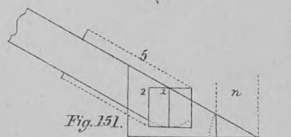


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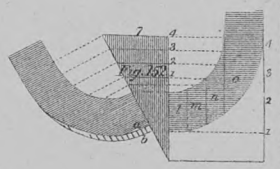
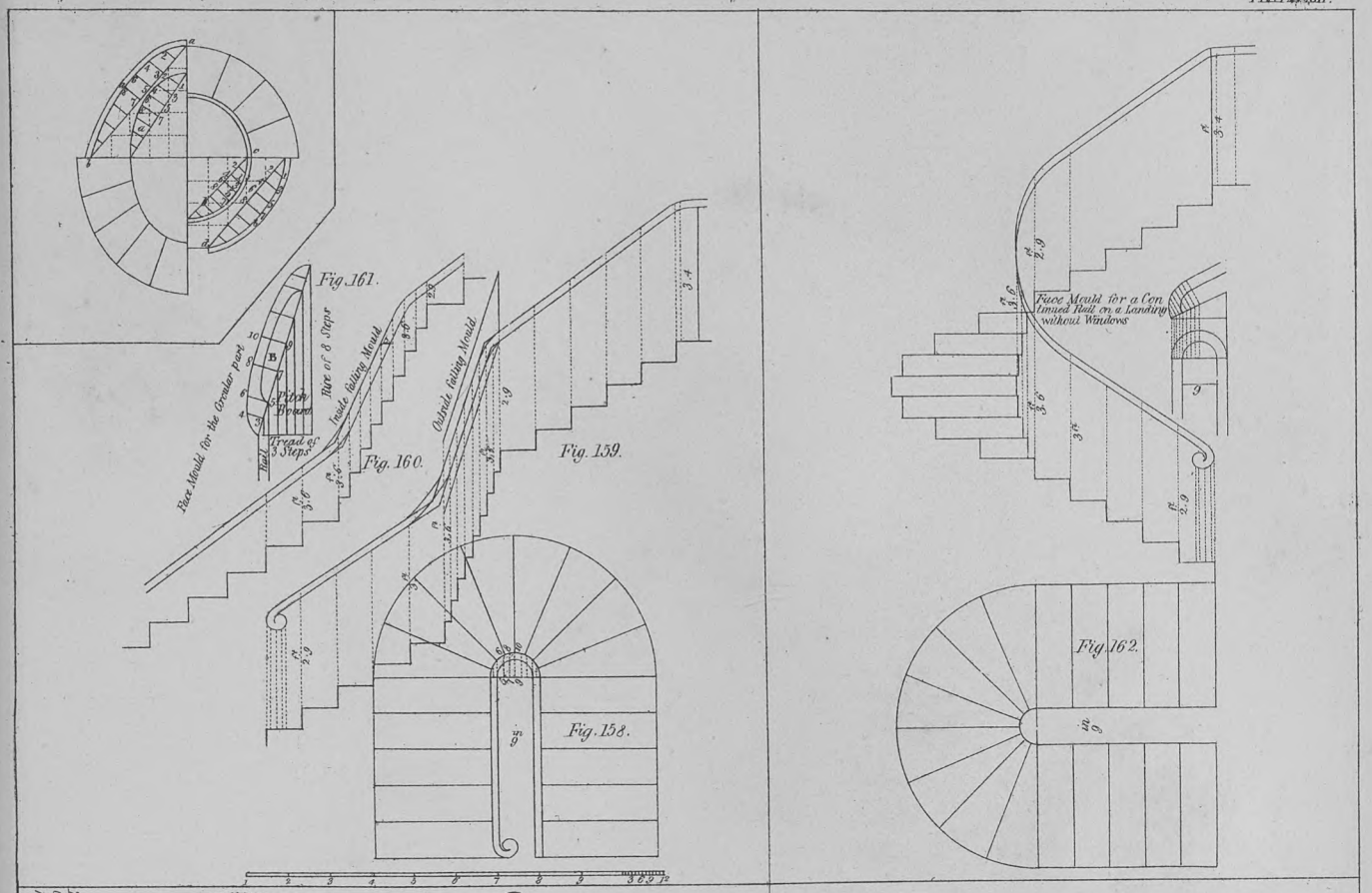
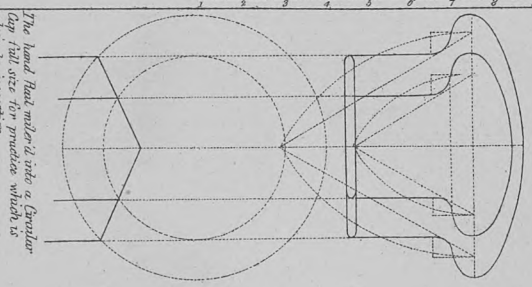


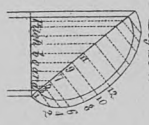
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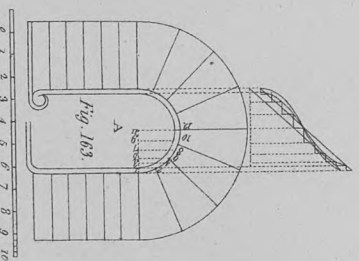
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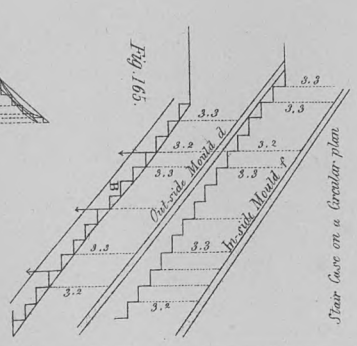
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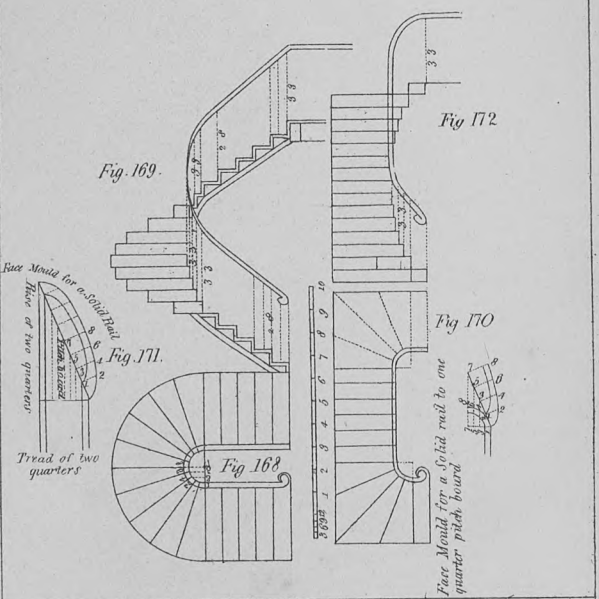












Drawn by M.A.Nicholson

Engraved by J.C.Buttre

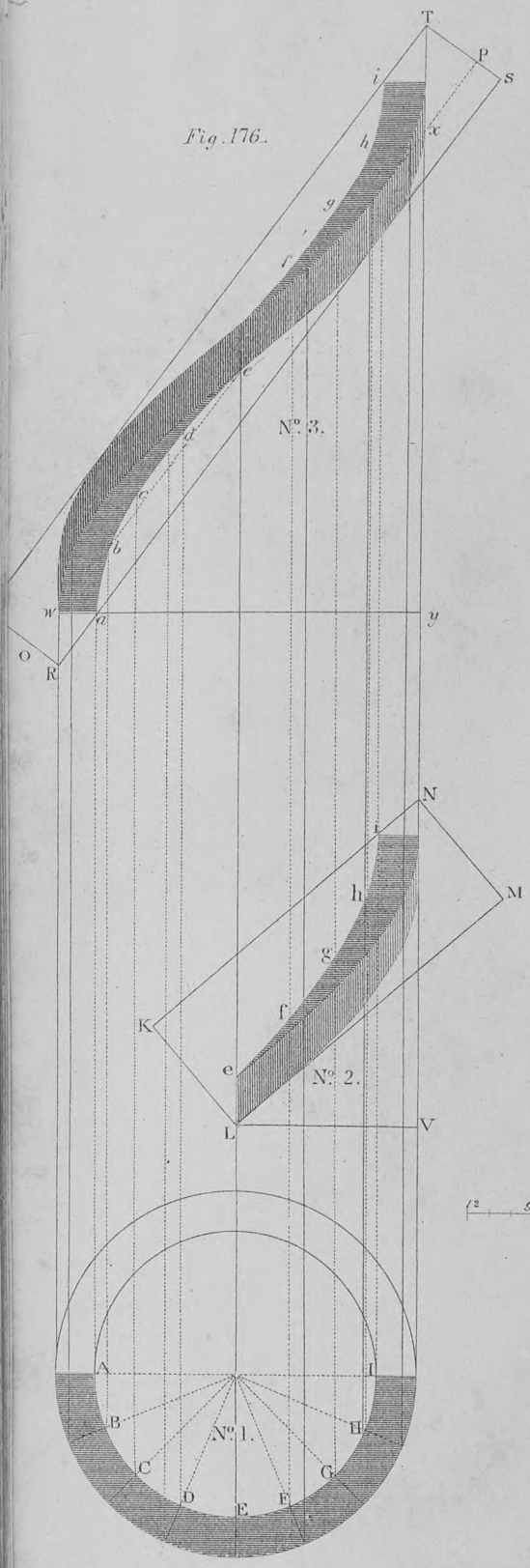


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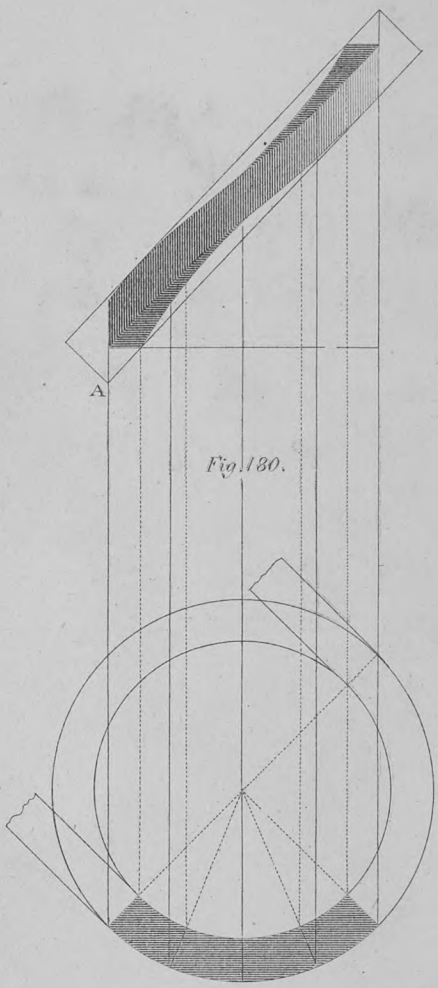


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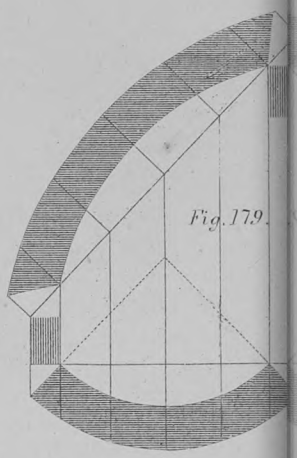
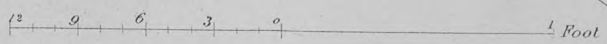


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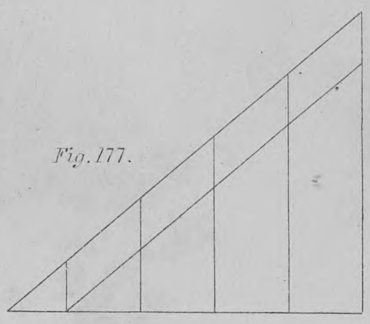


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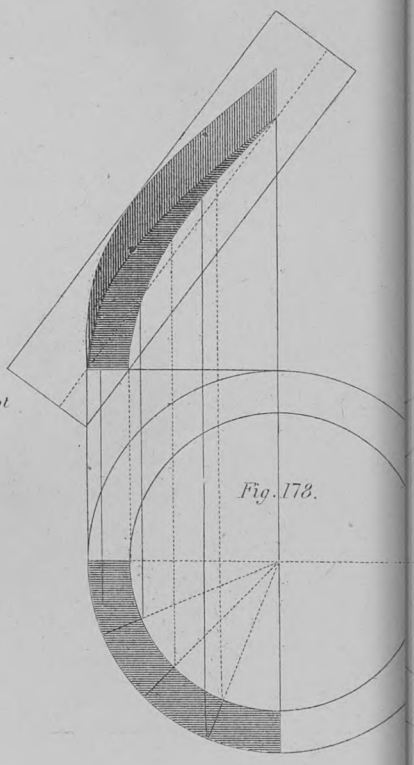


Fig. 178.

Drawn by M. A. Nicholson.

Engraved by J.C. Buttre.

JOINERY.

Fig. 181.

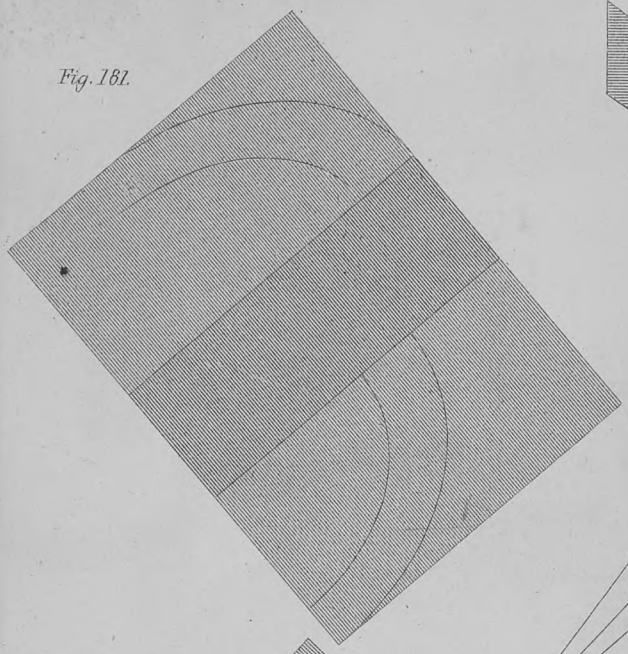
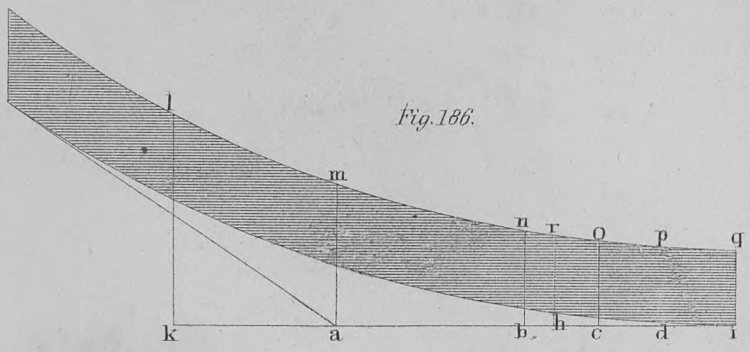


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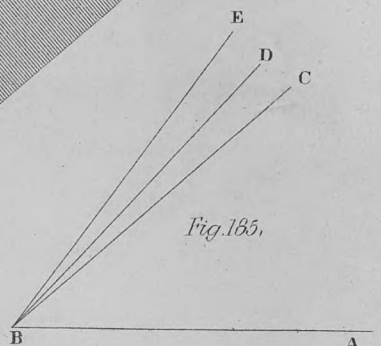


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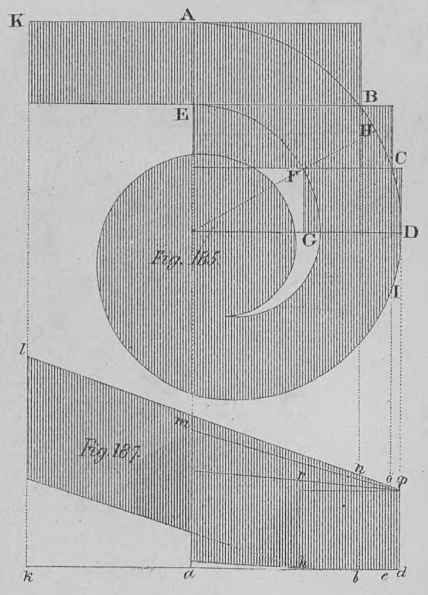


Fig. 185.

Fig. 184.

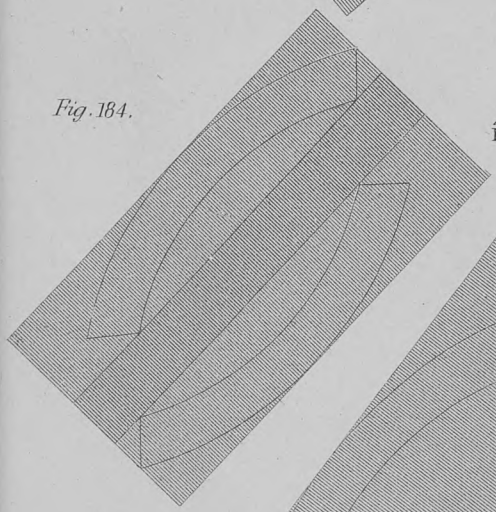


Fig. 187.

Fig. 182.

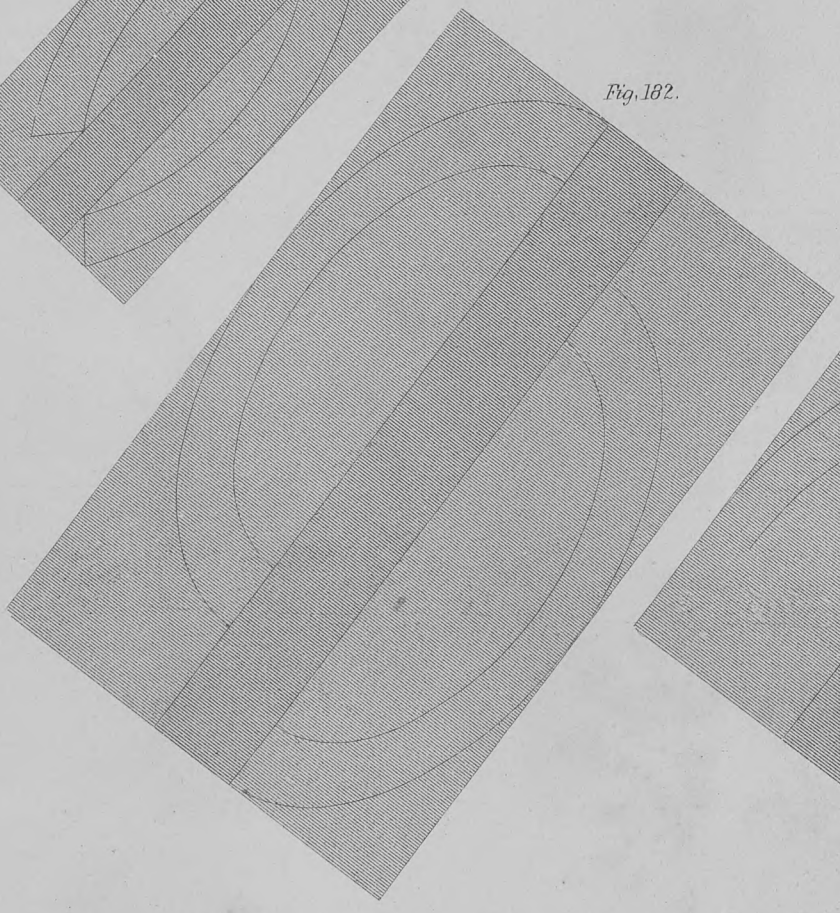
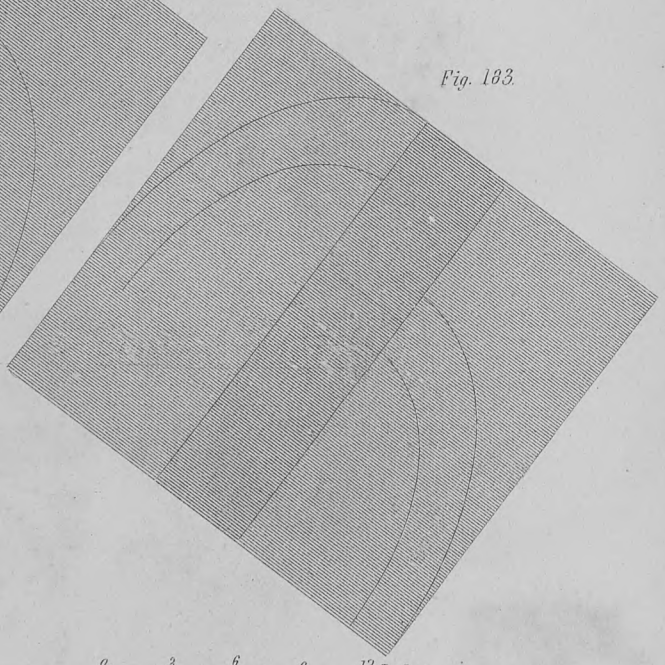
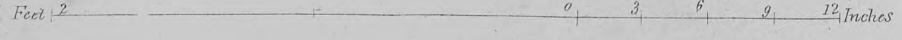


Fig. 183.





Drawn by M.A. Nicholson

Engraved by J.C. Buttre

Fig. 1.

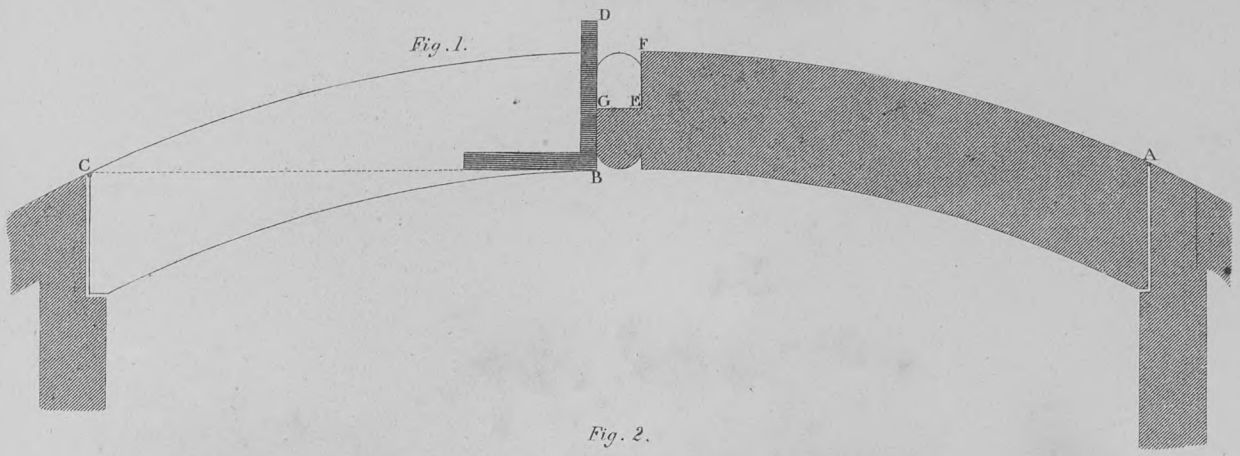


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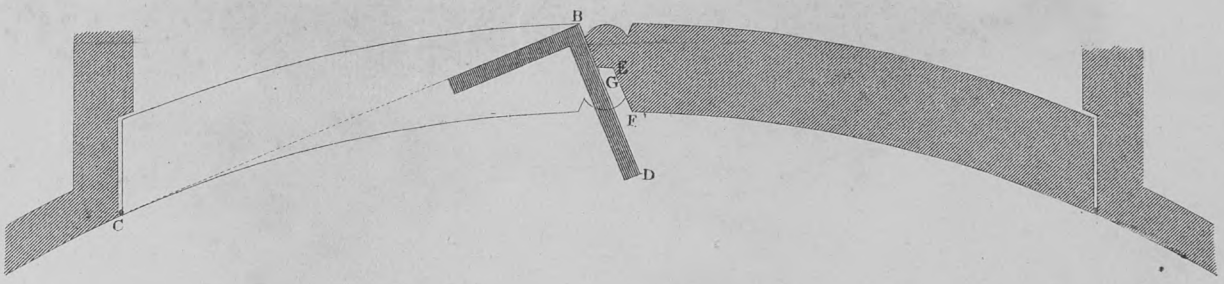


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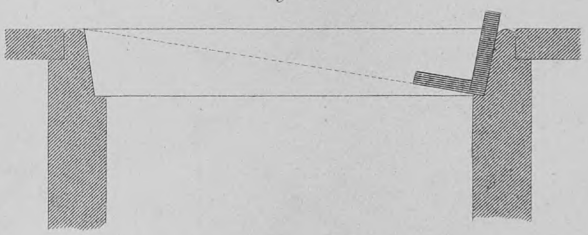


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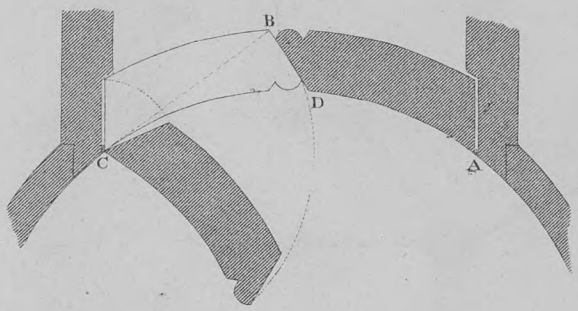


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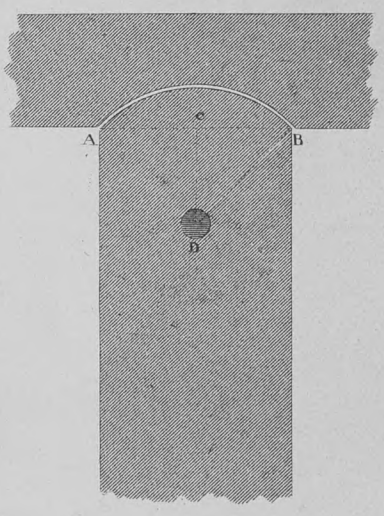


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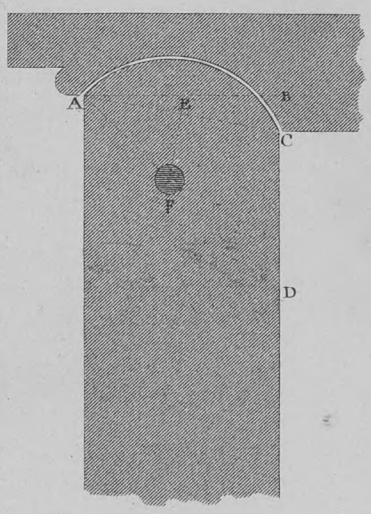
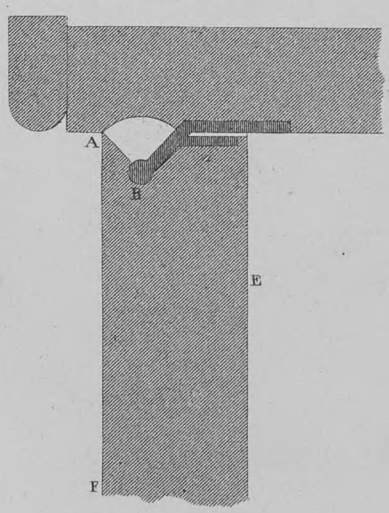


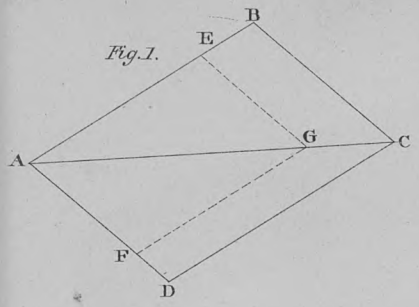
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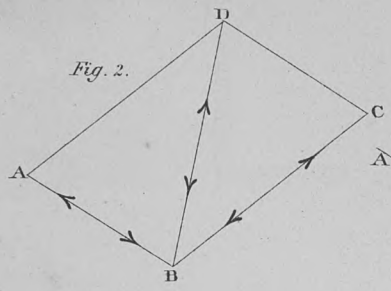


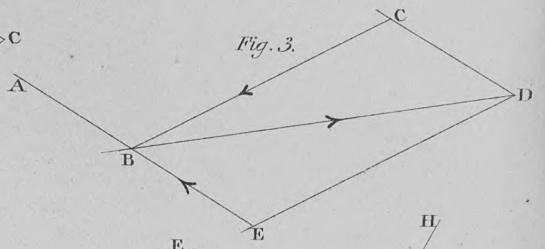
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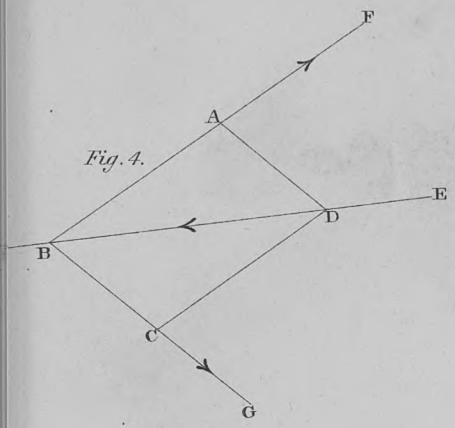
Engraved by J. C. Buttre.

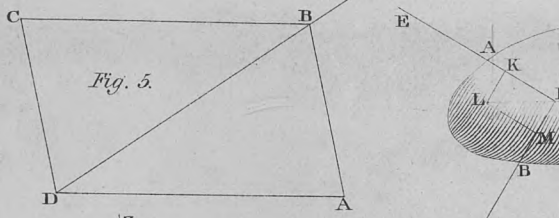
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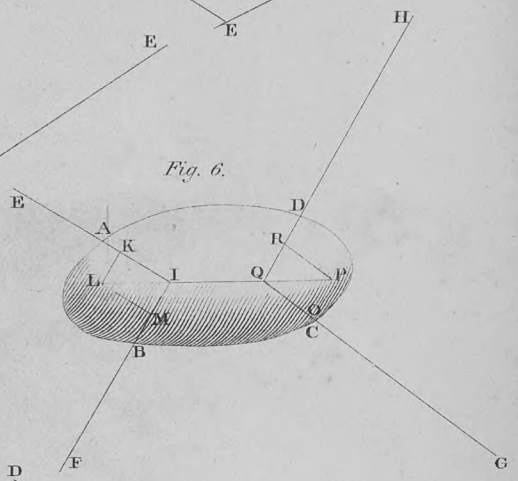


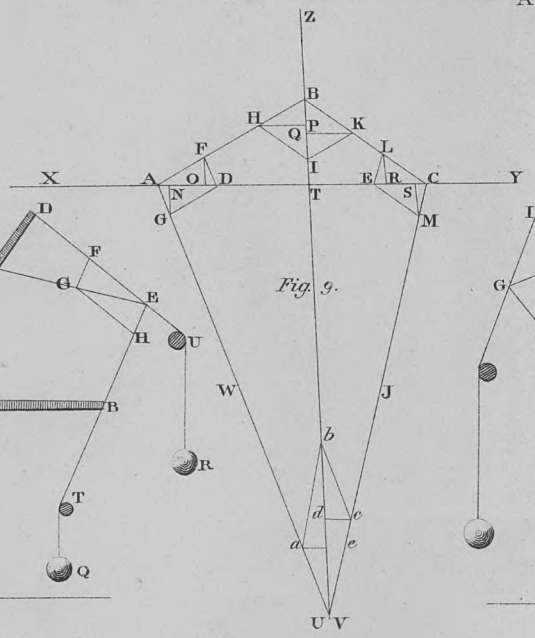


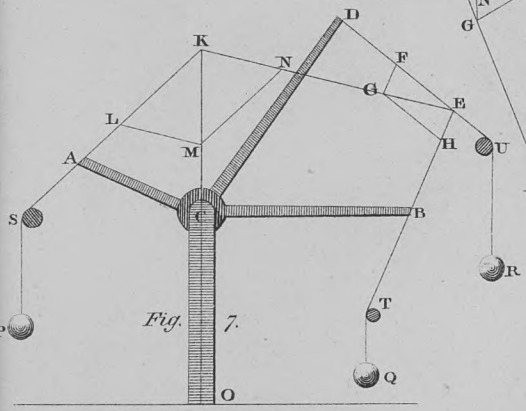


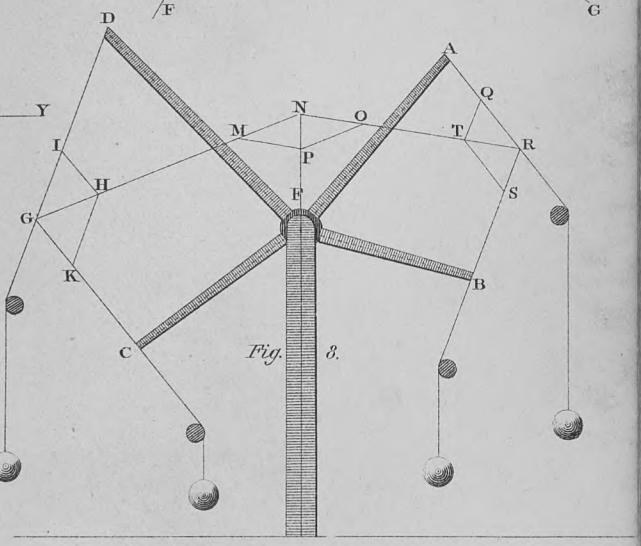


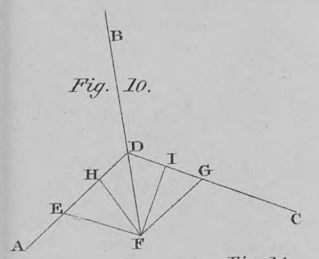


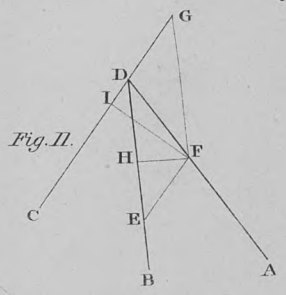


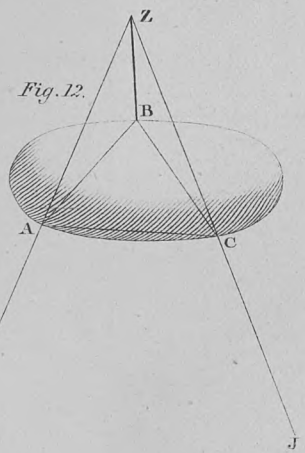


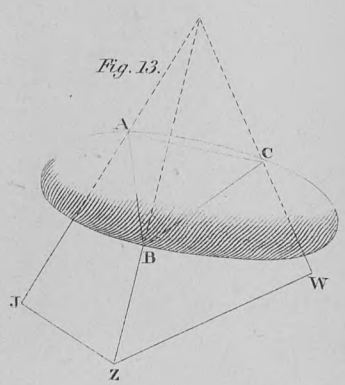


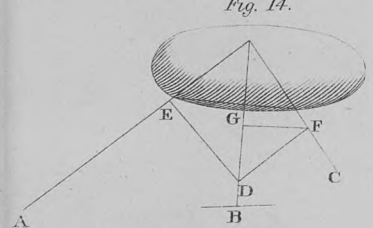










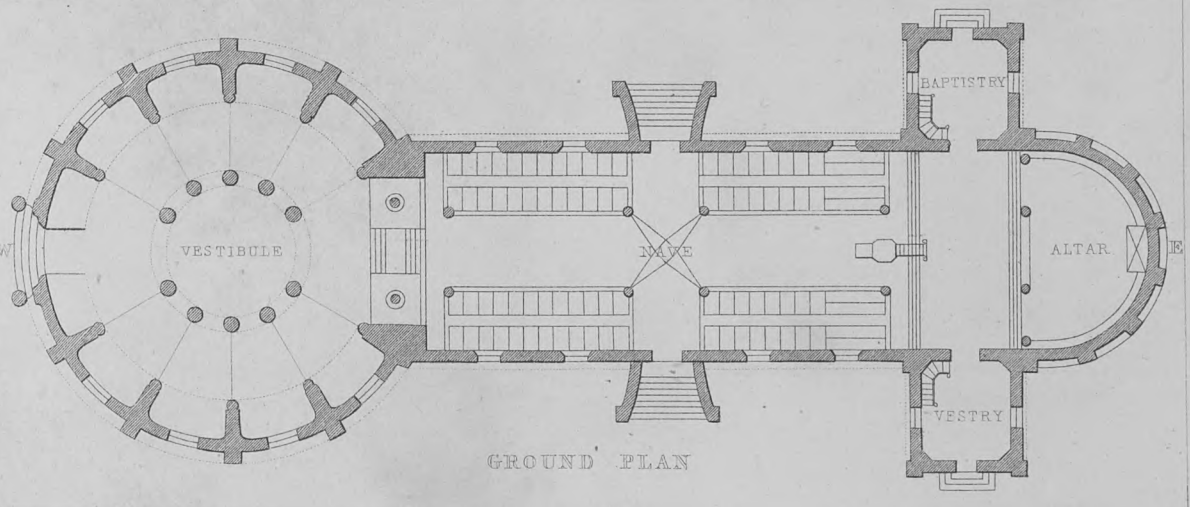


Drawn. by P. Nicholson.

Engd. by R. Thew.



EAST ELEVATION.

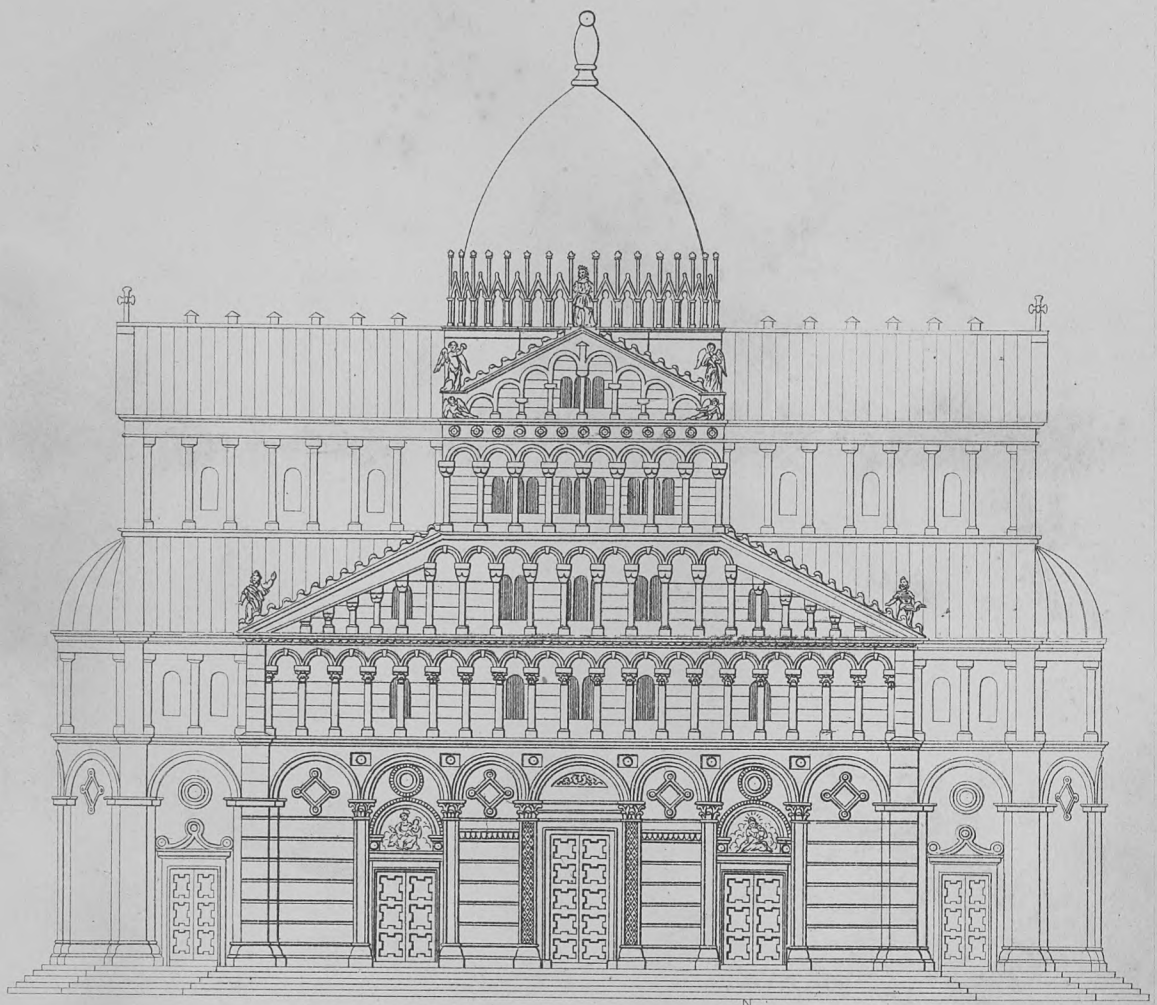


GROUND PLAN

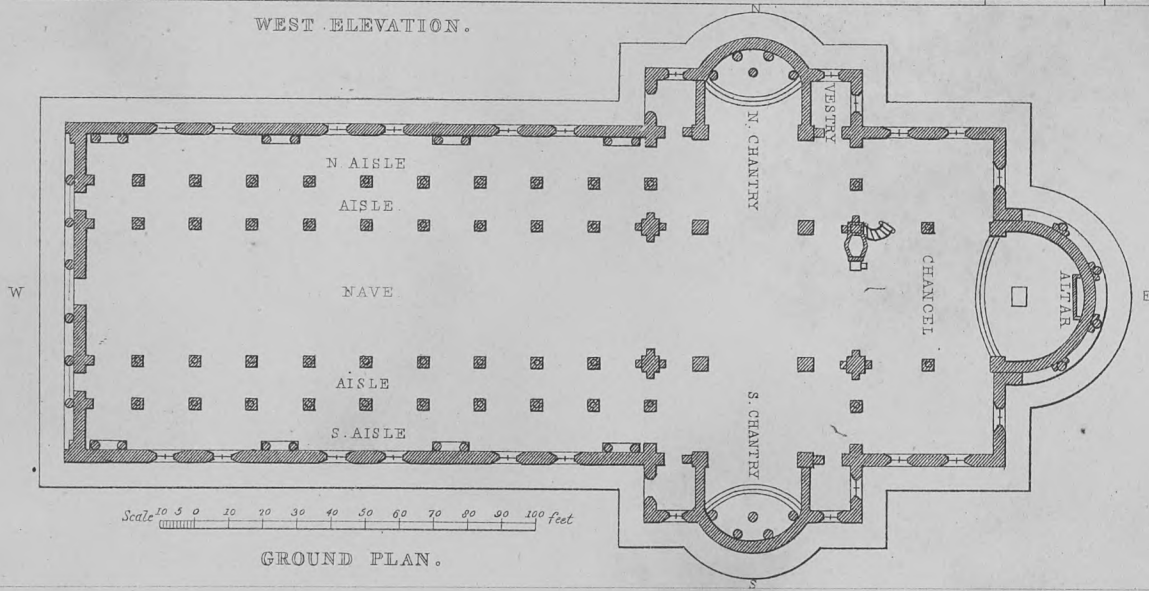
R.Brown Arch^t.

R. Thew.

PISA CATHEDRAL, LOMBARD ARCHITECTURE.



WEST ELEVATION.



GROUND PLAN.

R. Brown. Archt.

E. Thew.

Fig. A.

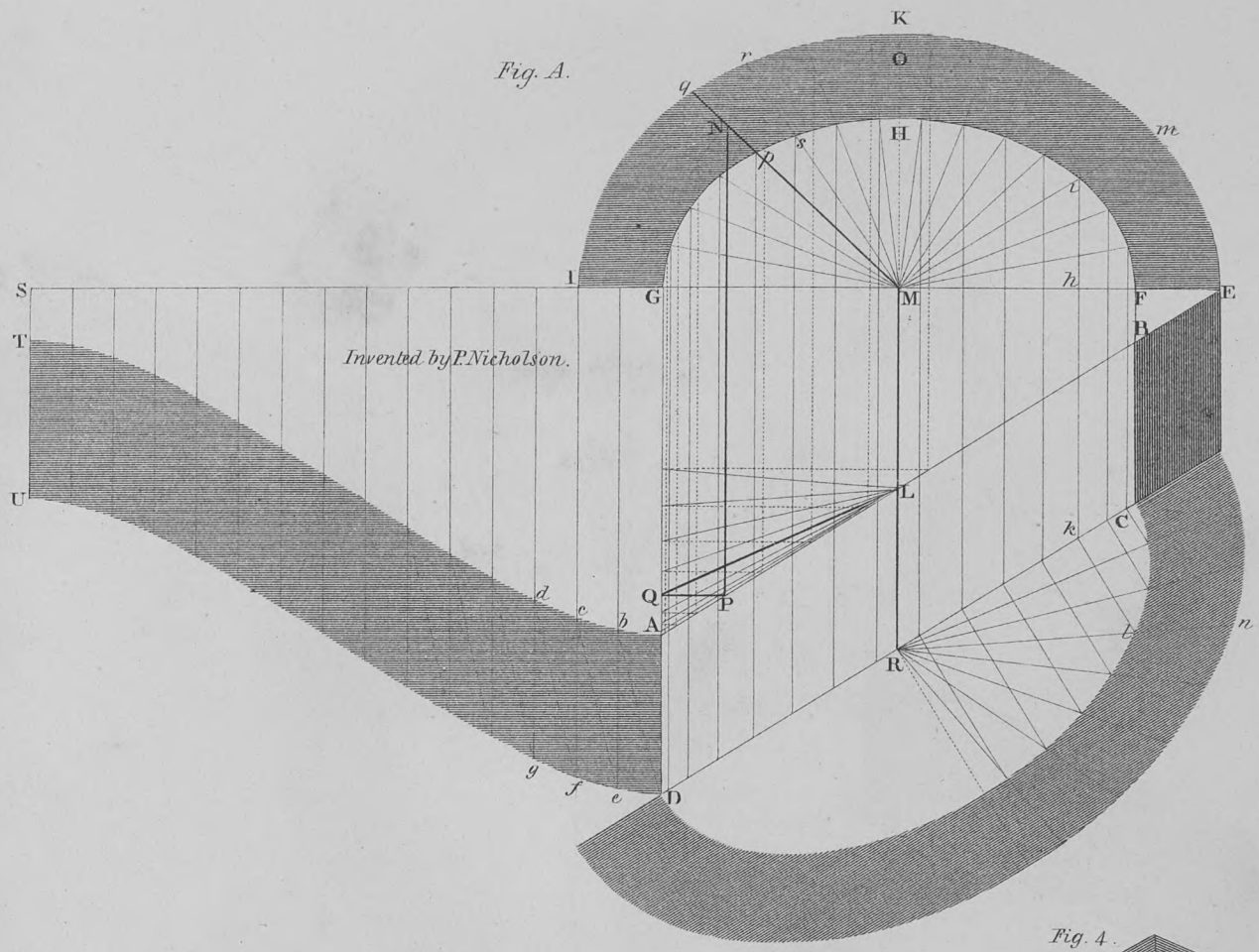


Fig. 1.

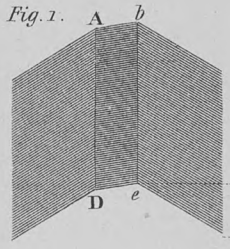


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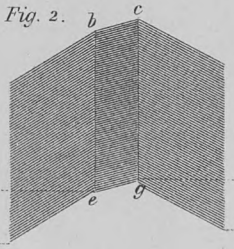


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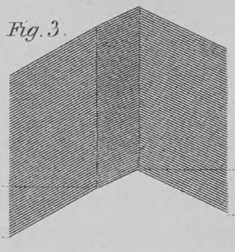


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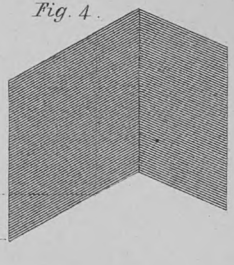


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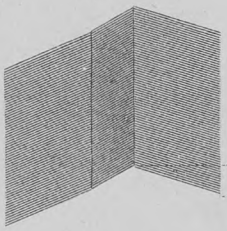


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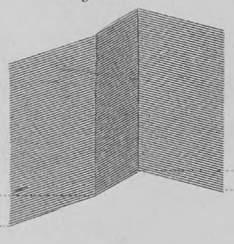


Fig. 7.

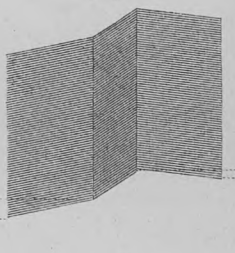
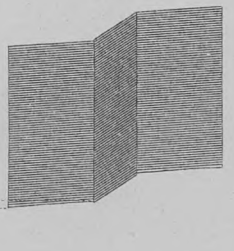


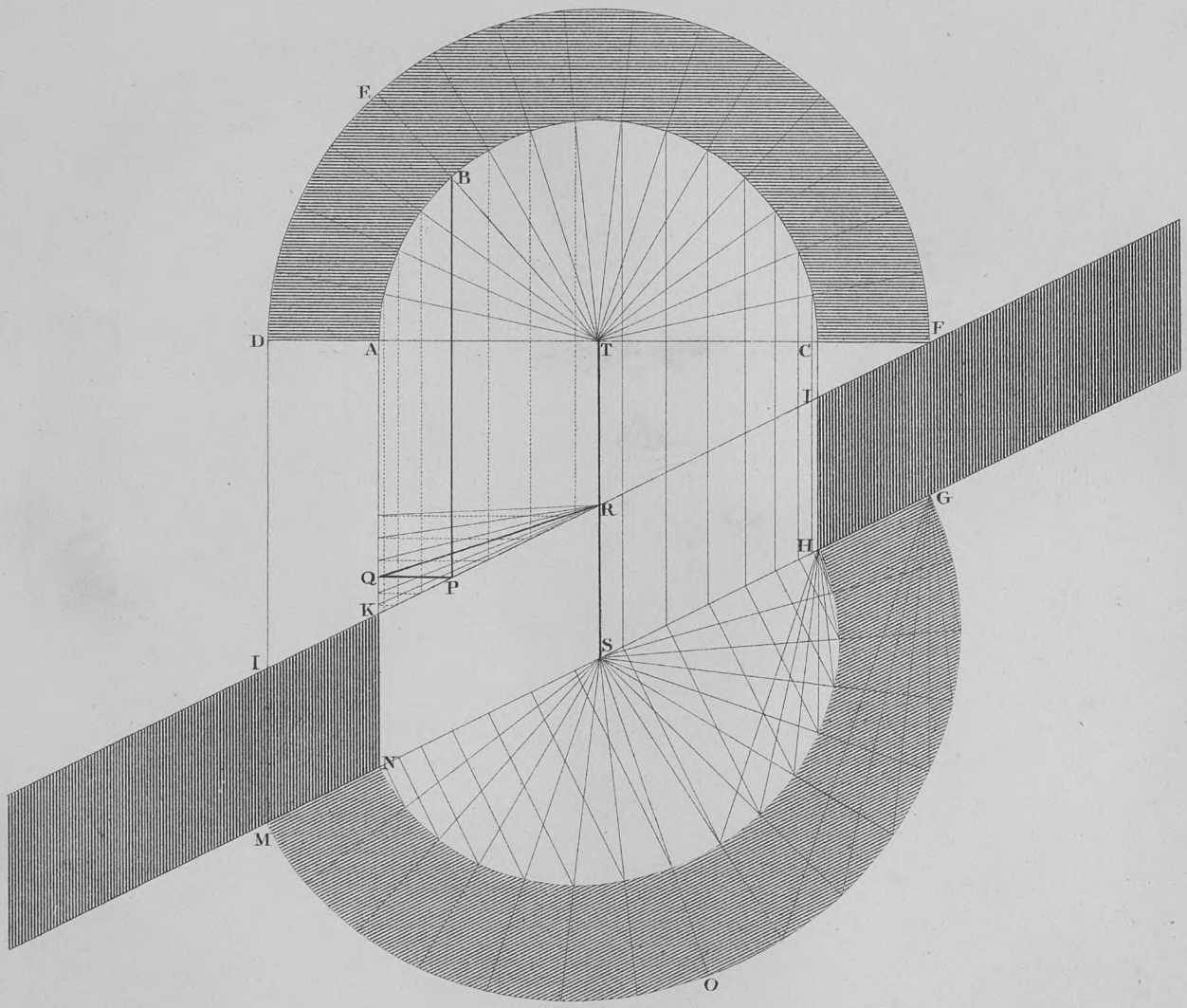
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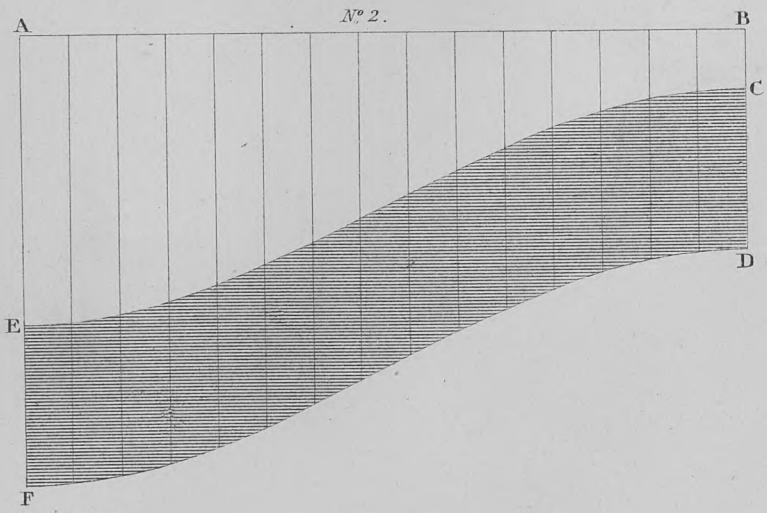
Drawn by M.A. Nicholson.

Engd. by R. Thew.

N° 1

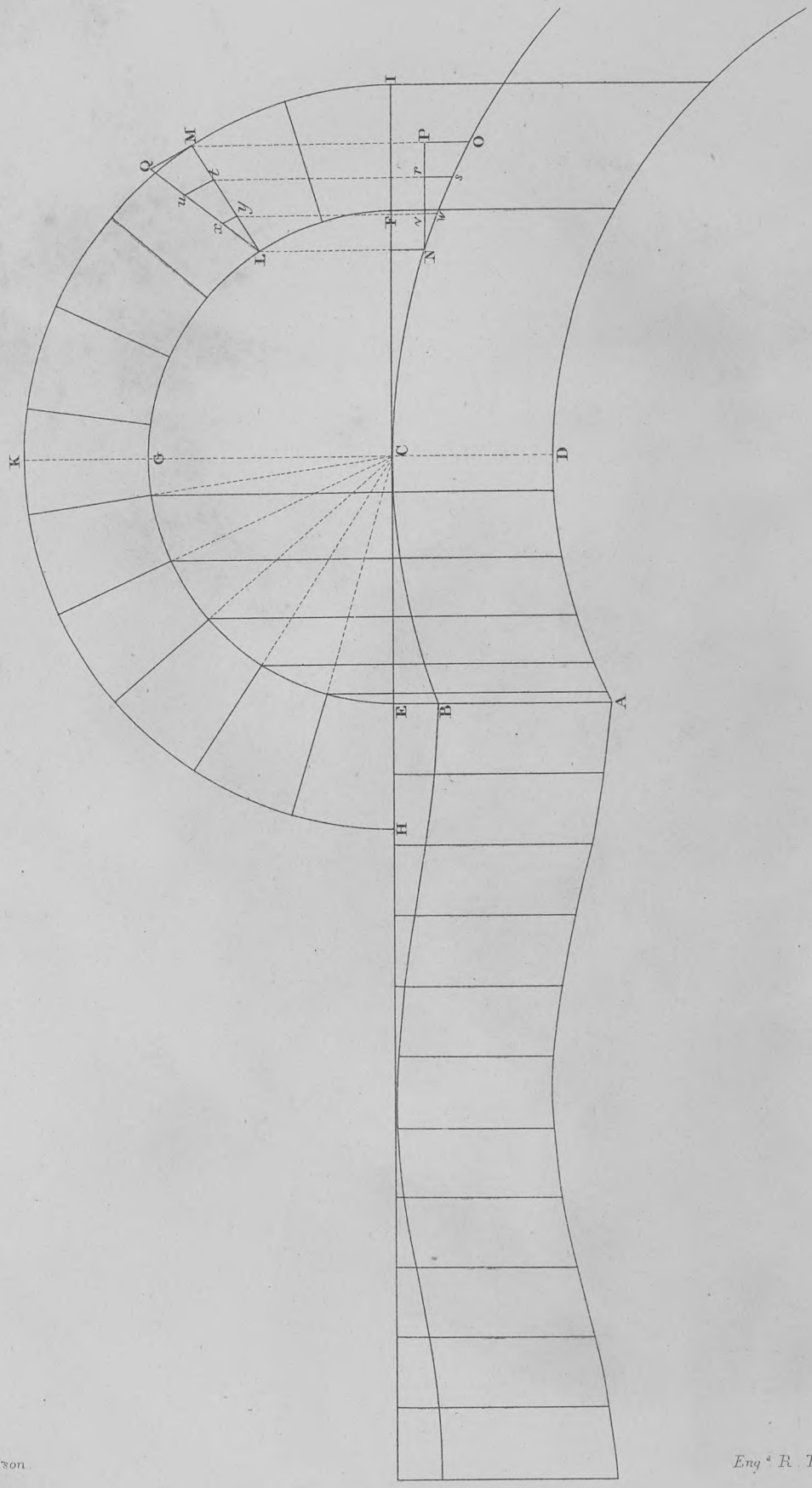


N° 2.



Drawn. by. P. Nicholson.

Engd. by. R. Thew.



Drawn by P. Nicholson.

Engd R. Thew.

Fig. 1.

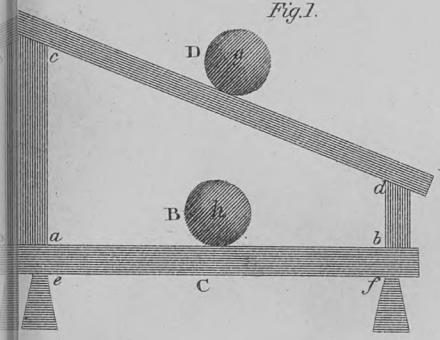


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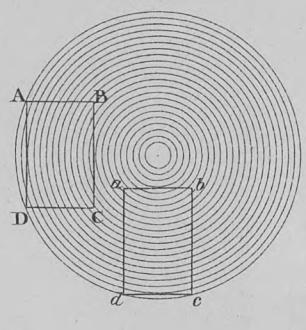


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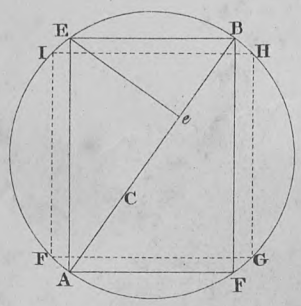
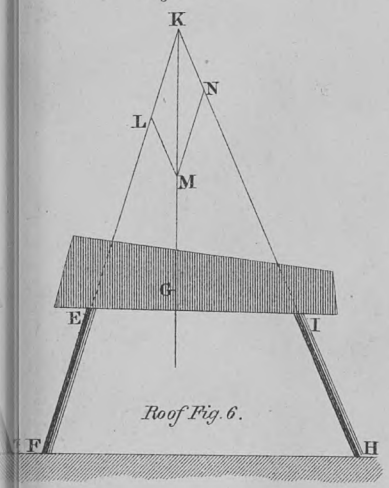


Fig. 4.



Roof Fig. 6.

Fig. 5.

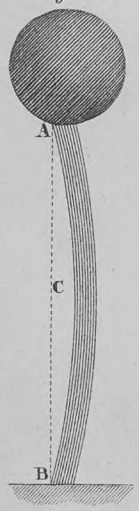
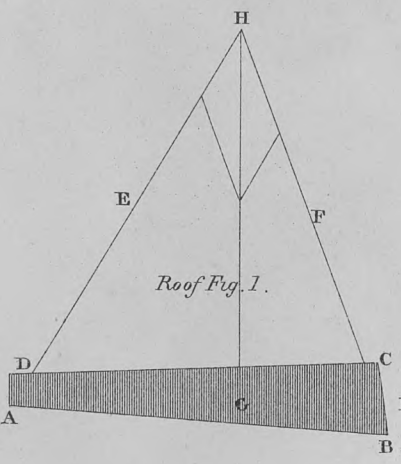
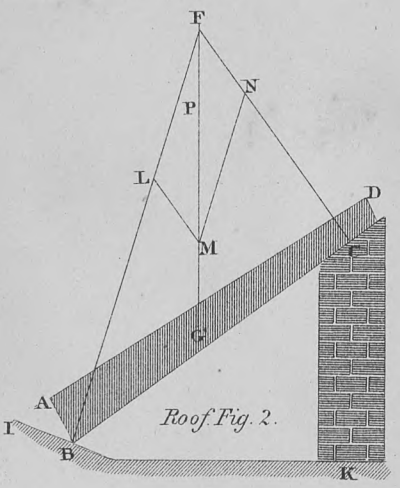


Fig. 6.



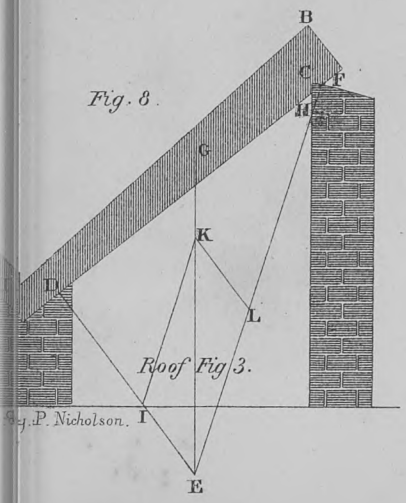
Roof Fig. 1.

Fig. 7.



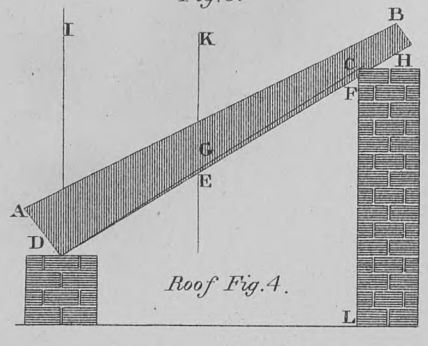
Roof Fig. 2.

Fig. 8.



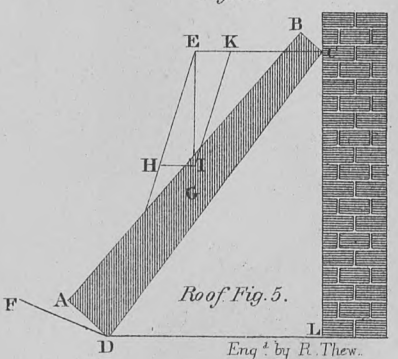
Roof Fig. 3.

Fig. 9.



Roof Fig. 4.

Fig. 10.

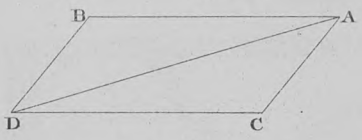


Roof Fig. 5.

Engd by P. Nicholson.

Engd by R. Thew.

Fig. 11.



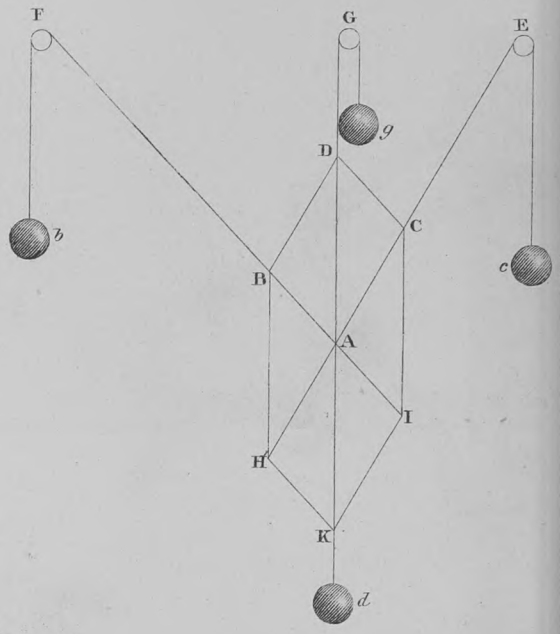


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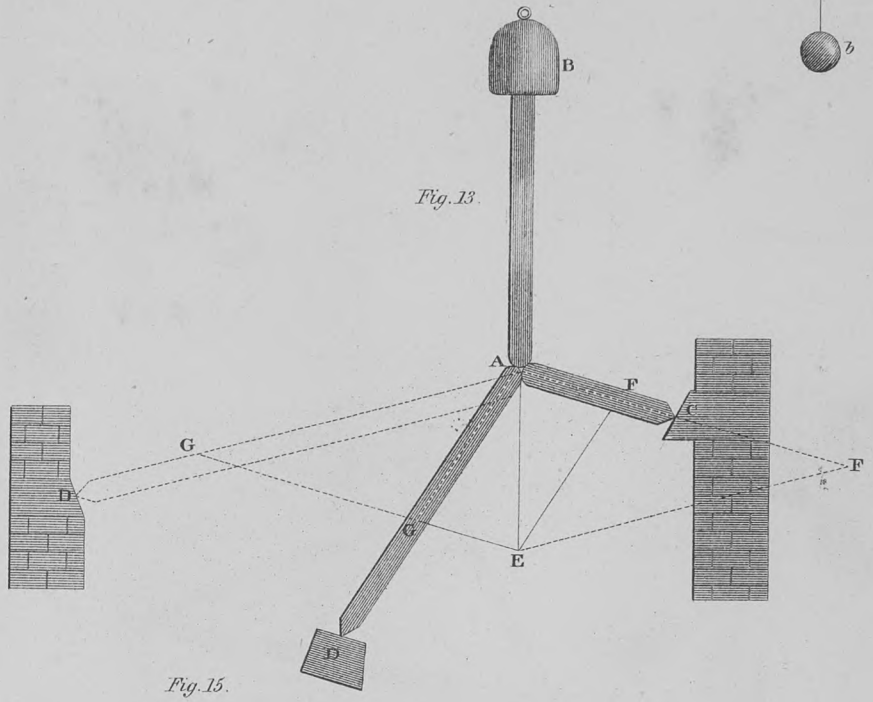


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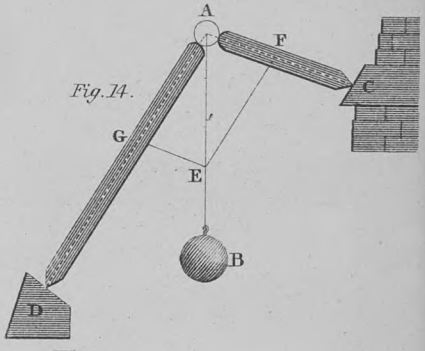


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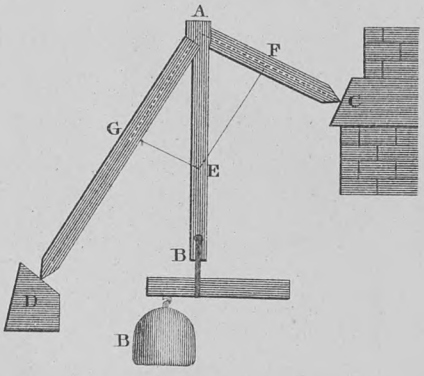


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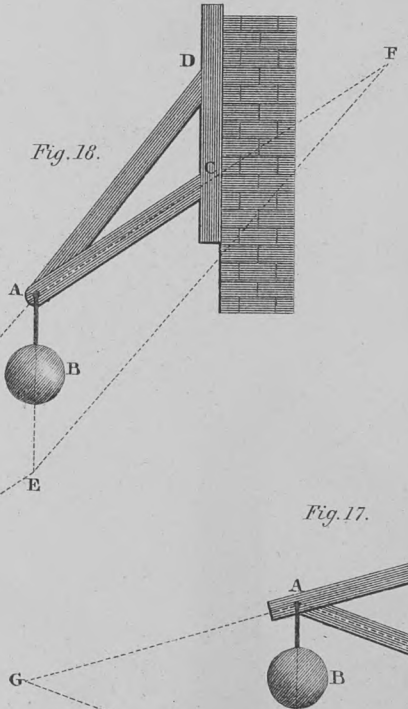
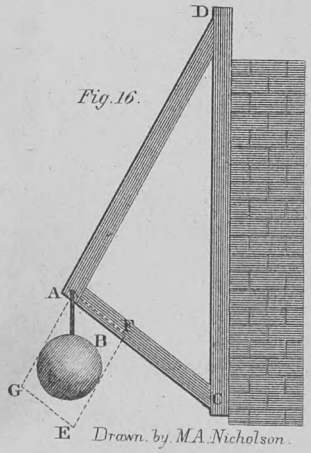
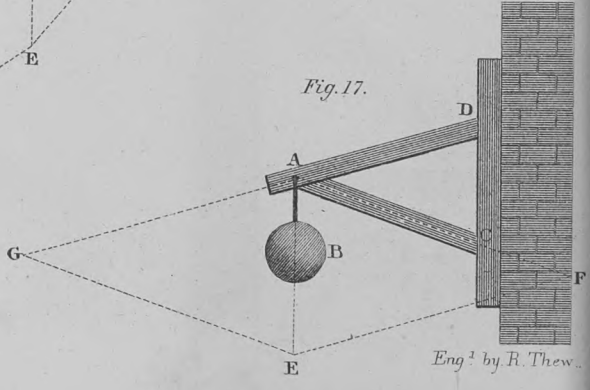


Fig. 16.



Drawn. by M.A. Nicholson.

Fig. 17.



Engd. by R. Thew.

Fig. 19.

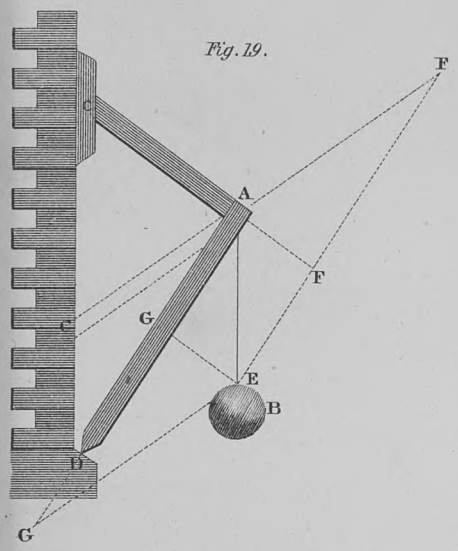


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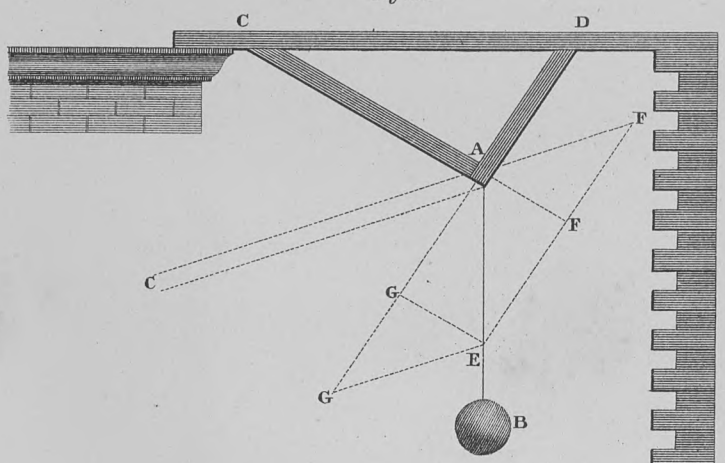


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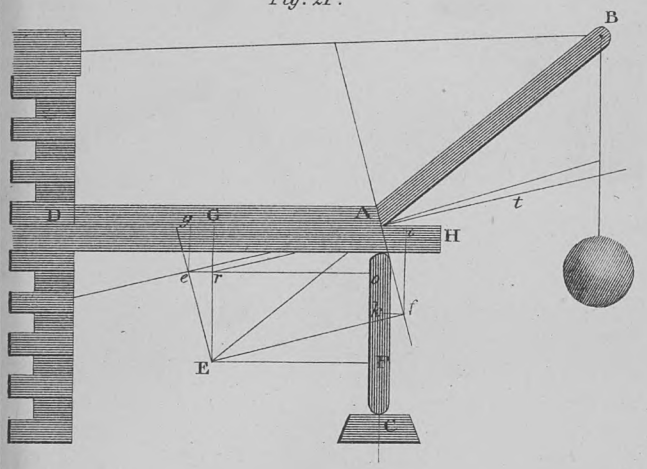


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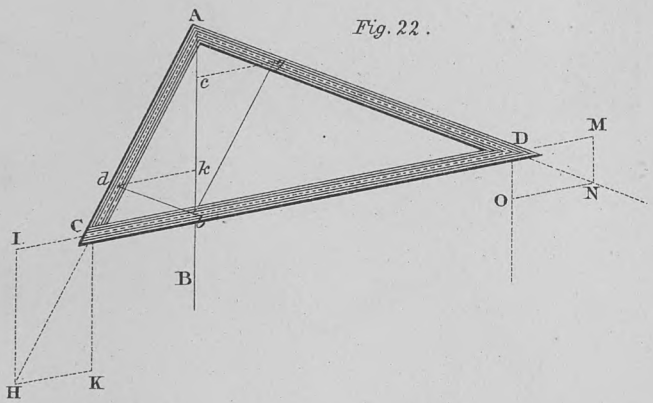


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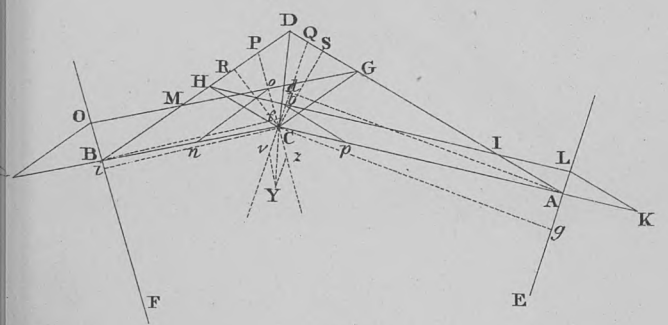


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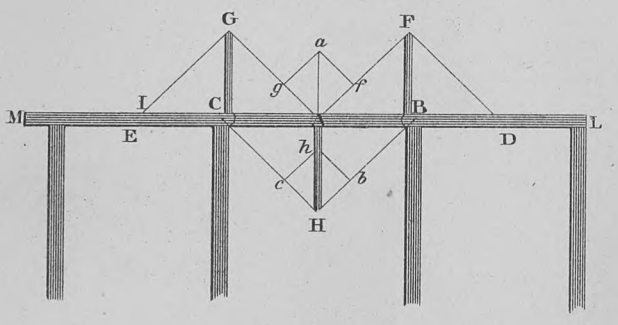


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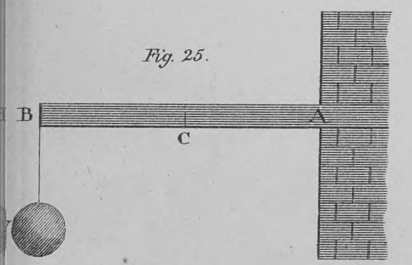
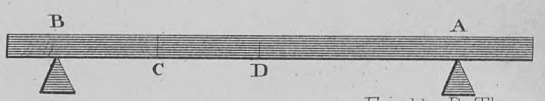


Fig. 26.



Drawn by M. A. Nicholson.

Engd by R. Thew.

Fig. 27.

A

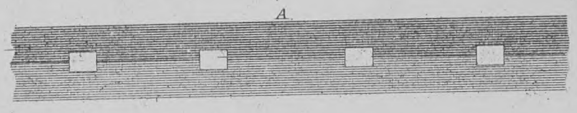


Fig. 27.

B

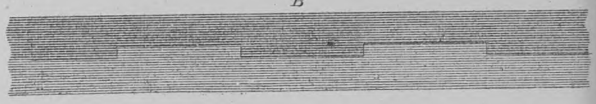


Fig. 27.

C

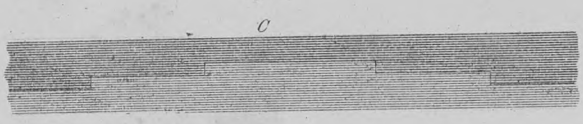


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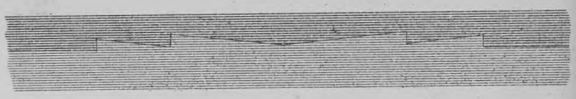


Fig. 29.



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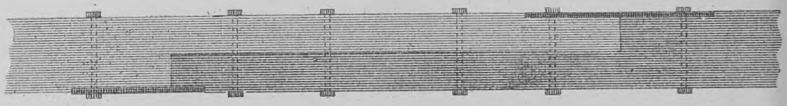


Fig. 30. N°. 2.



Fig. 30. N°. 3.



Fig. 31 N°. 1.

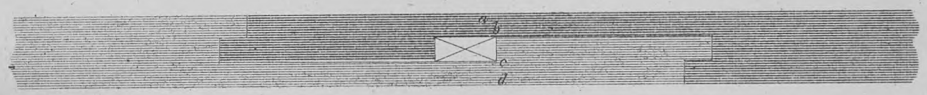


Fig. 31 N°. 2

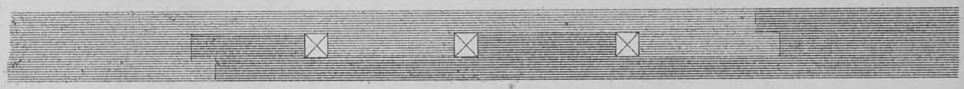


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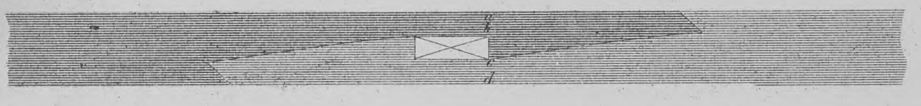
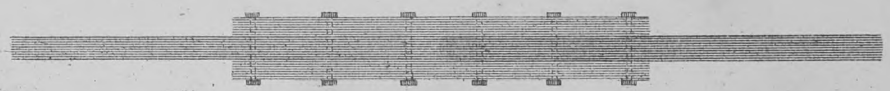


Fig. 33.



Drawn by M.A. Nicholson

Engraved by J.C. Buttre

Fig 34

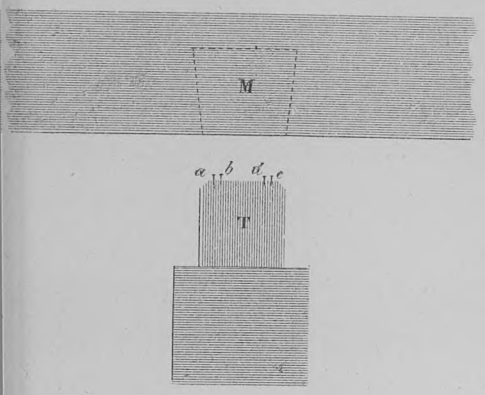


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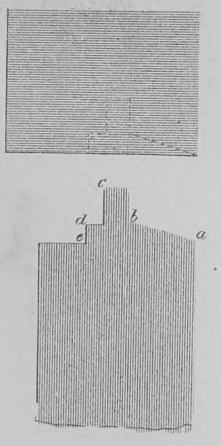


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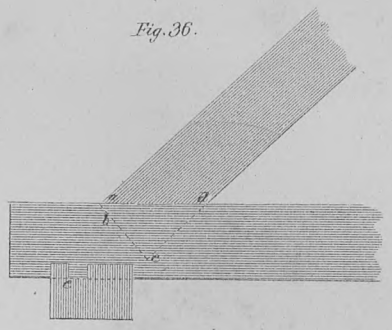


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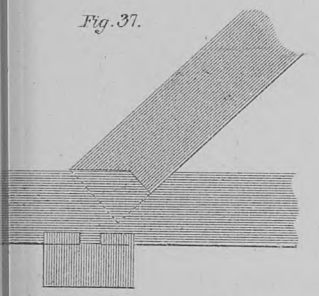


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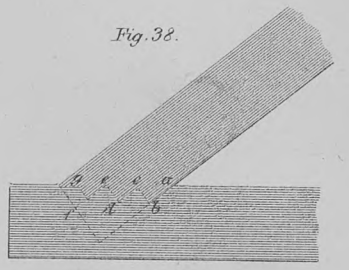


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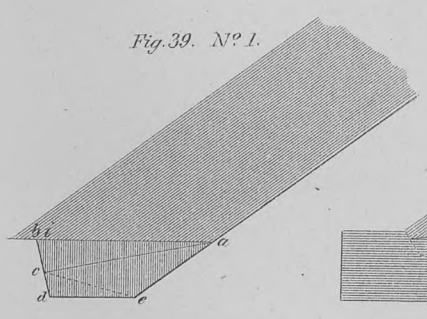


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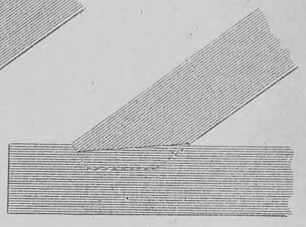


Fig. 40.

Fig. 39. N° 3.

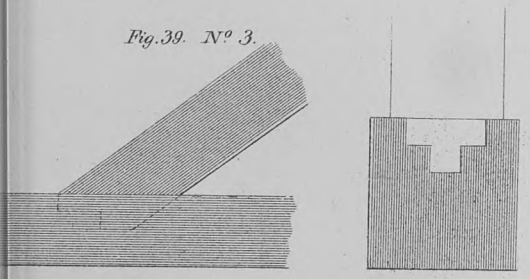


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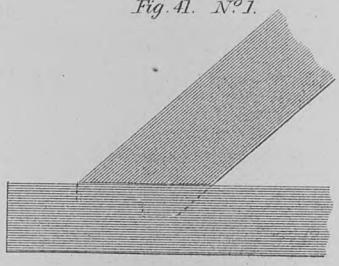


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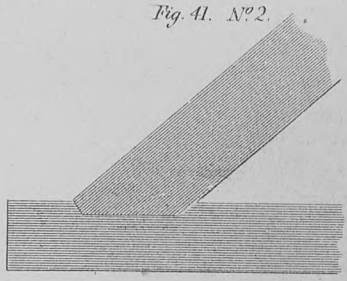


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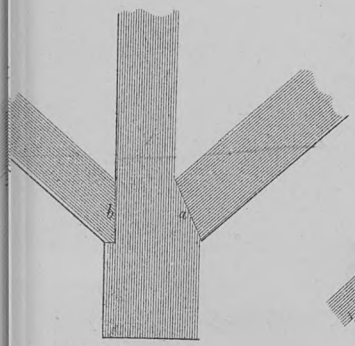
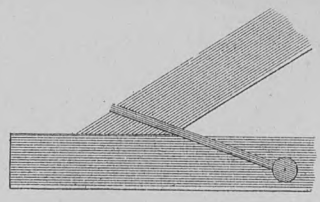


Fig. 42. N° 2.



Fig. 43.



Drawn by M.A.Nicholson

Engraved by J.C.Buttre

Fig. 1.

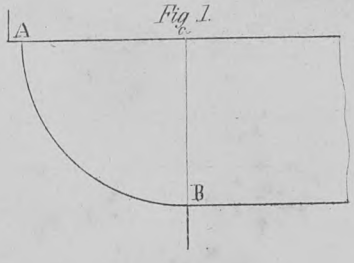


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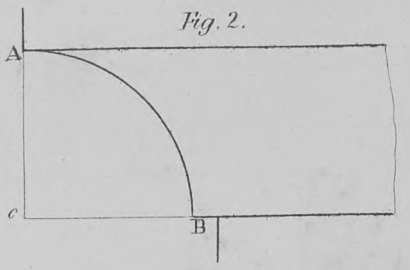


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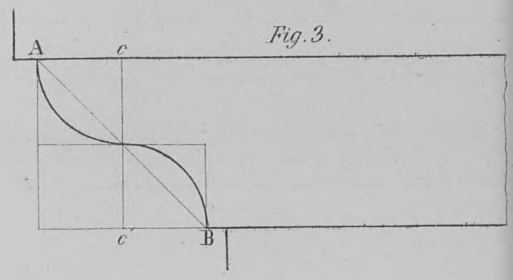


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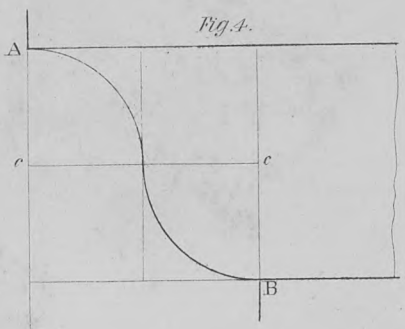


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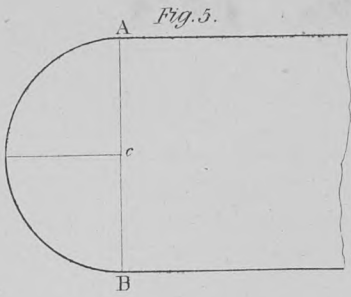


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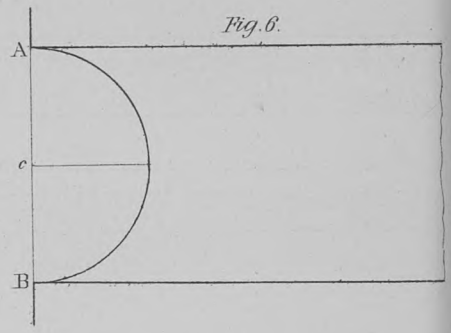


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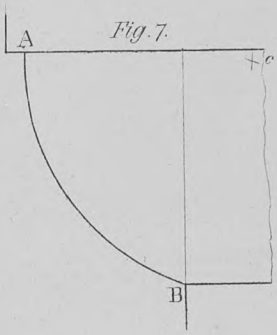


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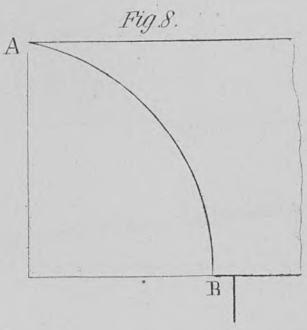


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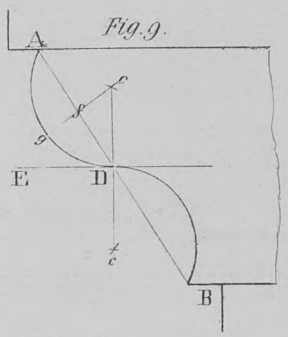


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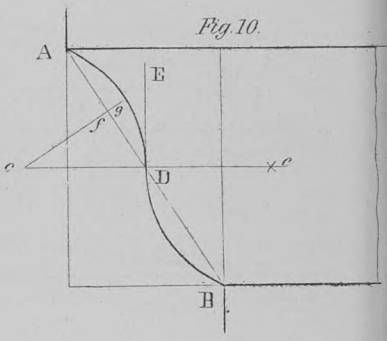


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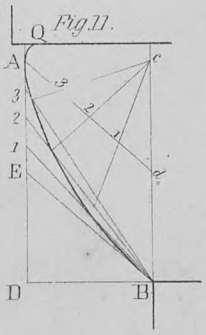


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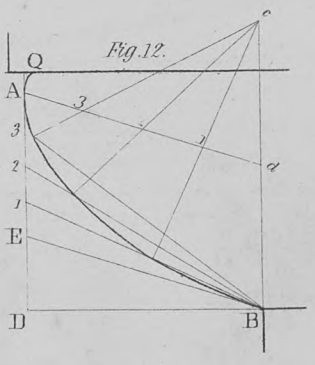


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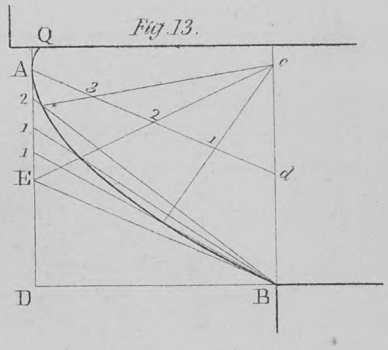


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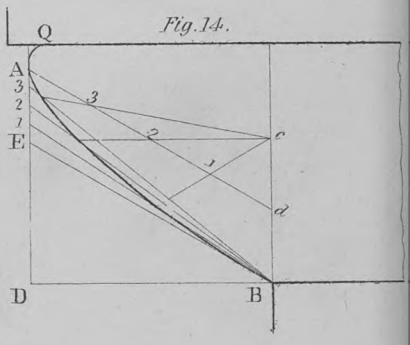


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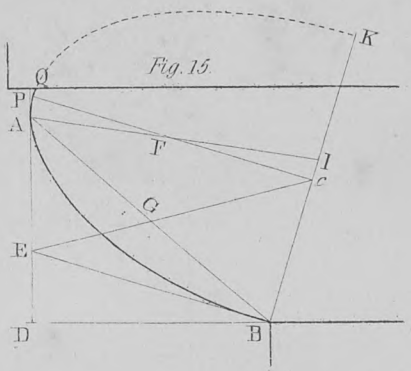


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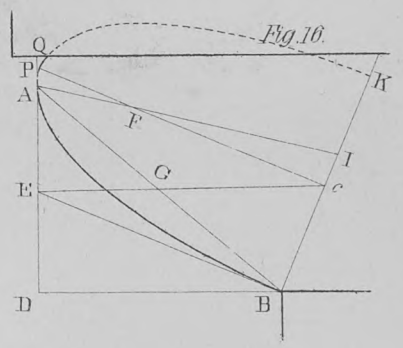
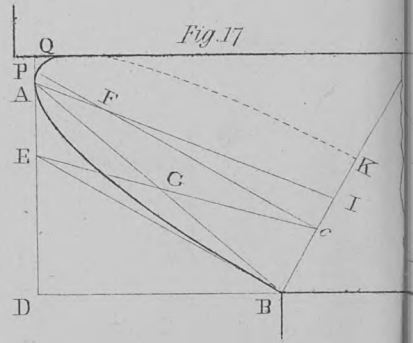


Fig. 17



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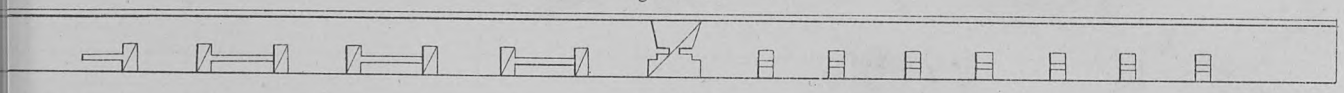


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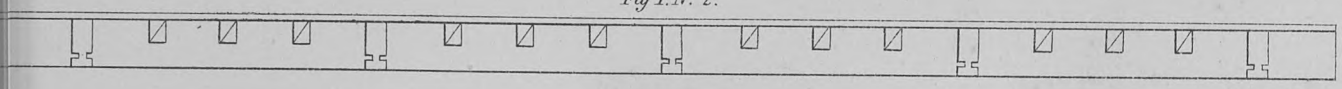


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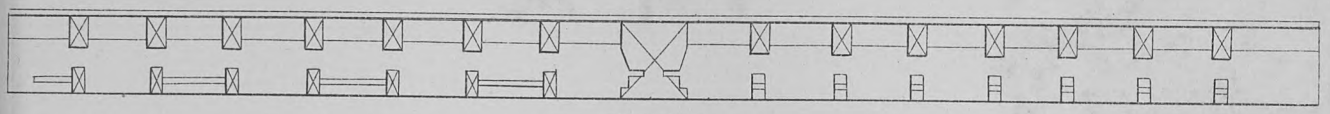


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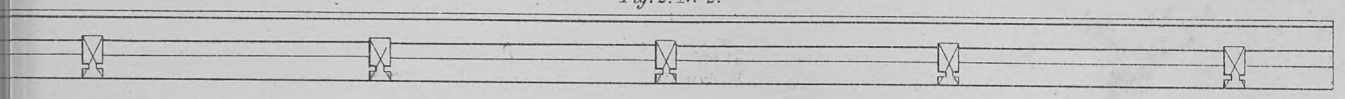


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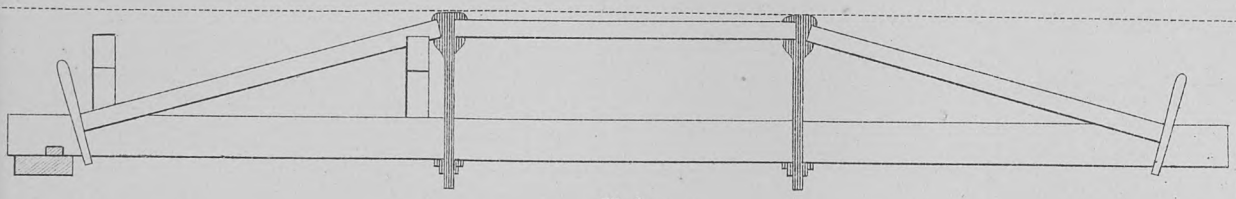


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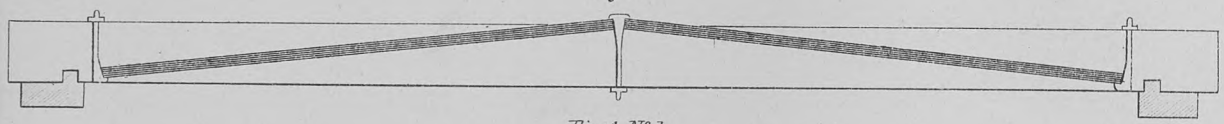


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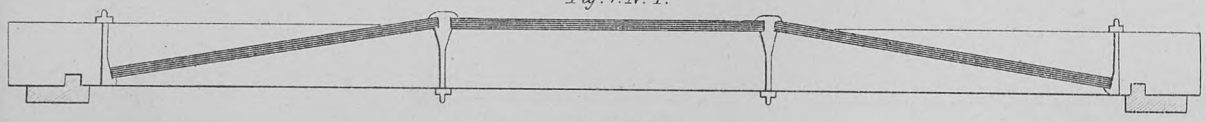
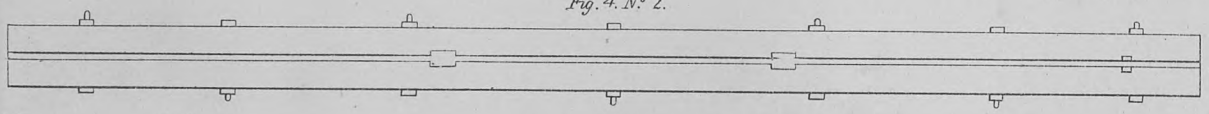


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N°. 1. *N° 2*

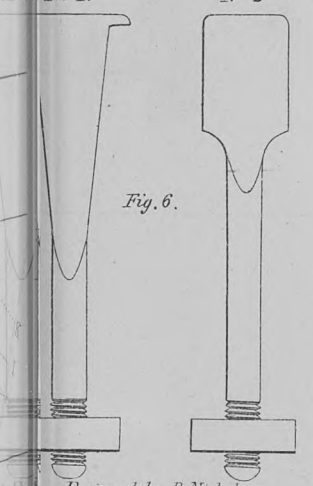


Fig. 6.

Designed by P. Nicholson
Drawn by M.A. Nicholson.

N°. 1. *N°. 2.*

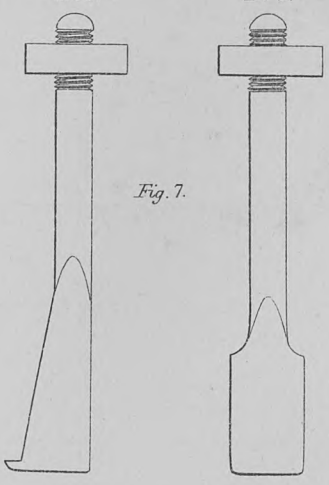
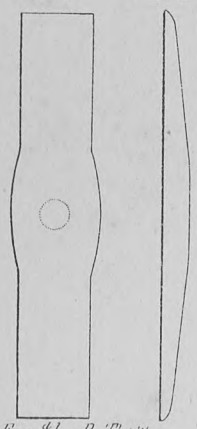


Fig. 7.

Fig. 8

N°. 1. *N° 2*



Eng^d by R. Thew.

NAKED FLOORING.

PLAT

Fig 1

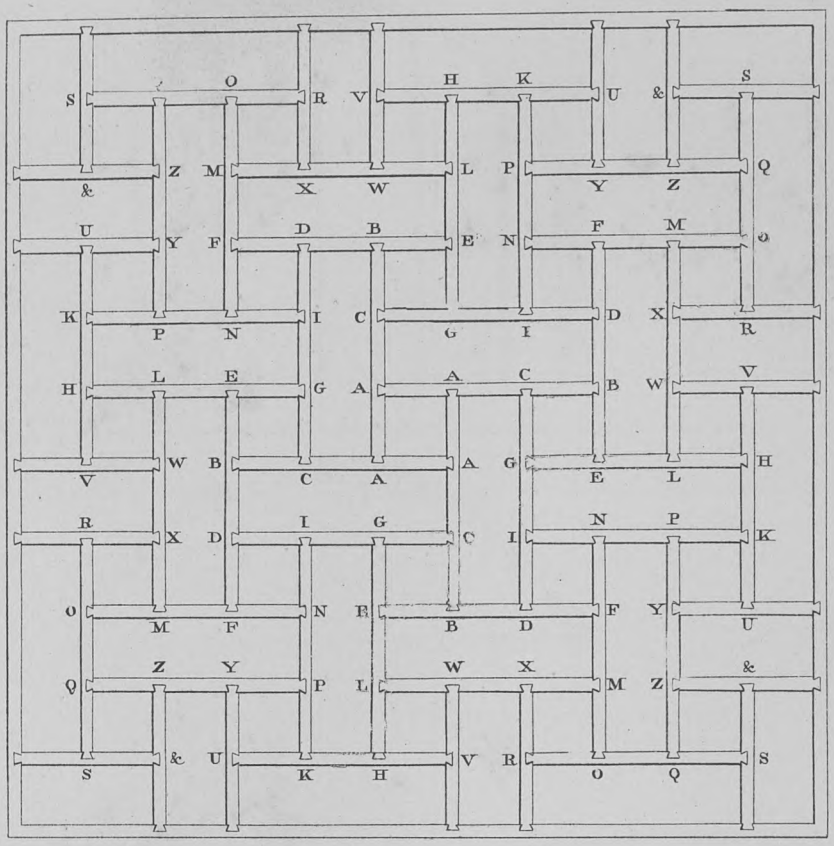


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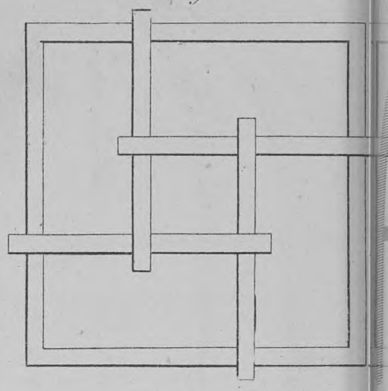


Fig. 5.



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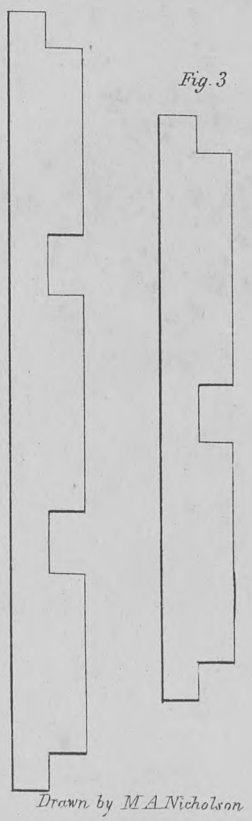


Fig. 3

Fig. 6.

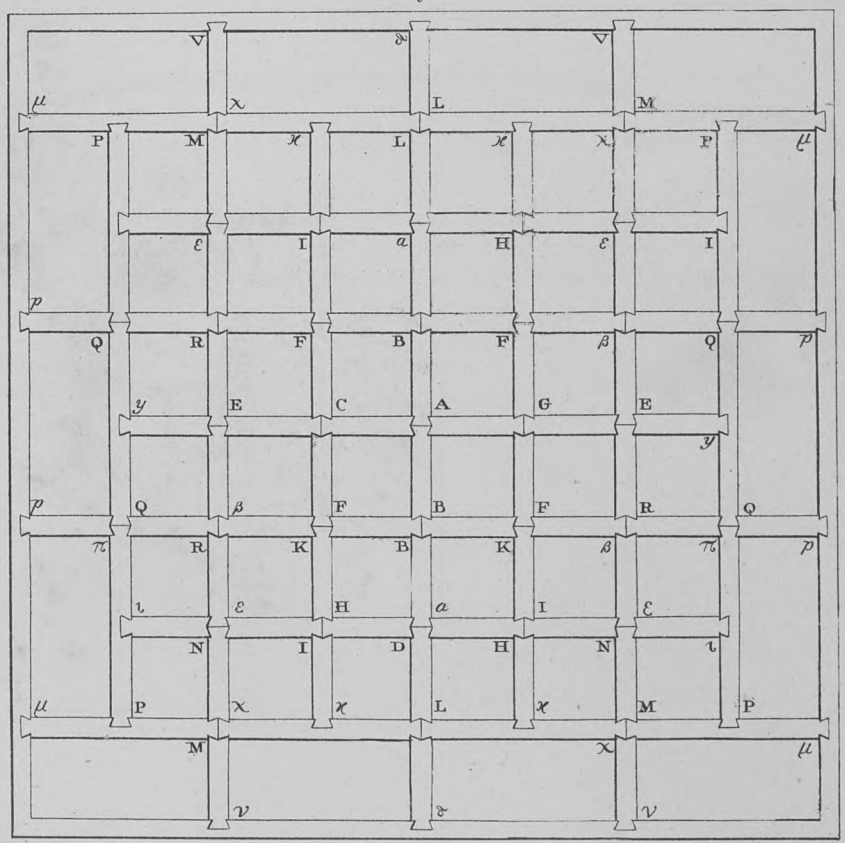
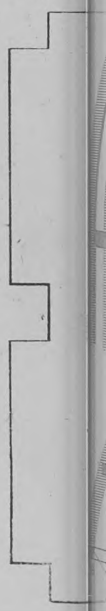


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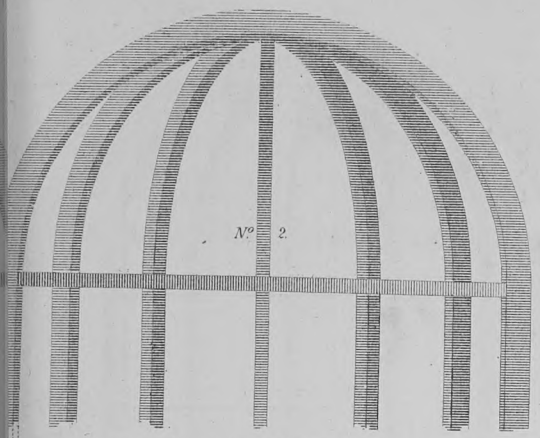


Drawn by M A Nicholson

Eng^d by R Thew

NICHES.

Fig. 1.



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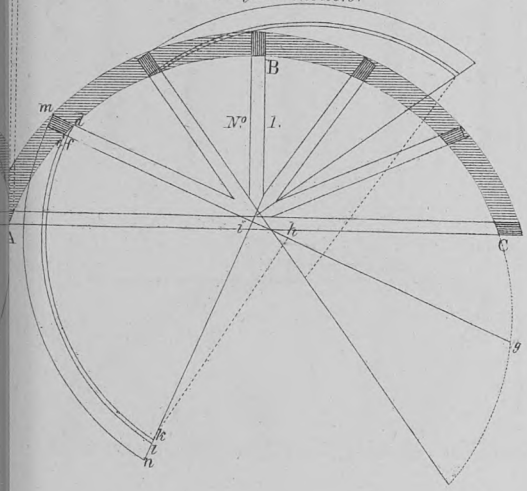
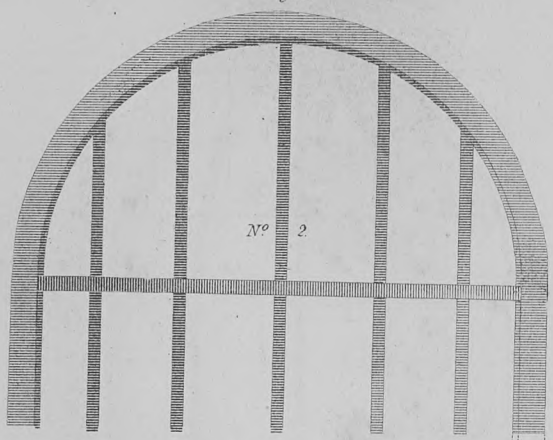


Fig. 2.



Invented by P. Nicholson.

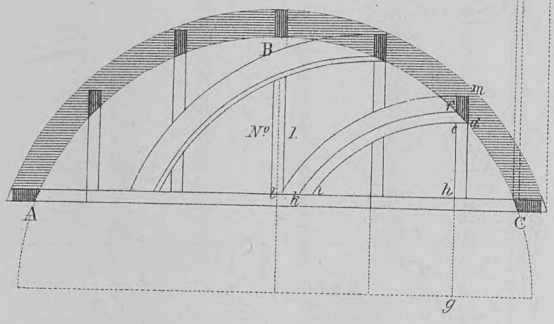
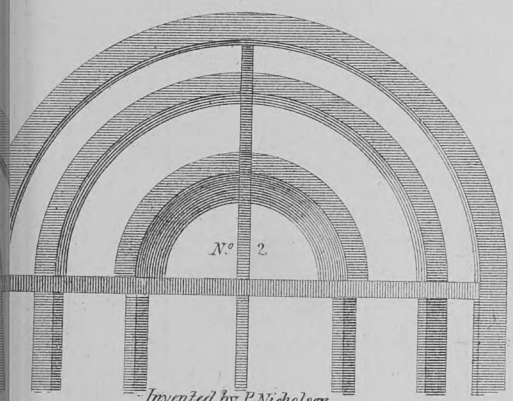


Fig. 3



Invented by P. Nicholson

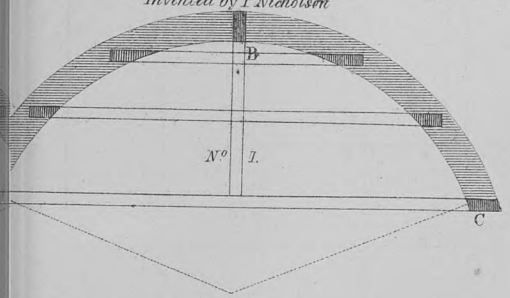
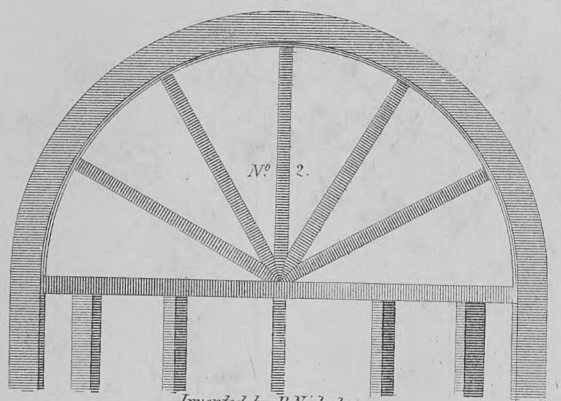
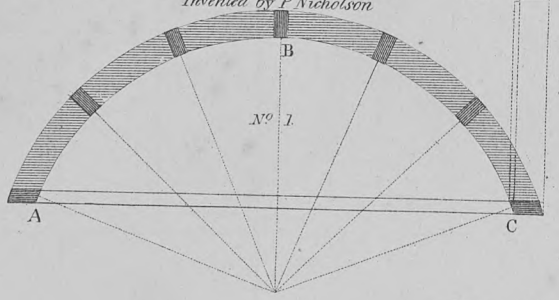


Fig. 4.



Invented by P. Nicholson



Nicholson

Engraved by J. C. Buttre

NICHES.

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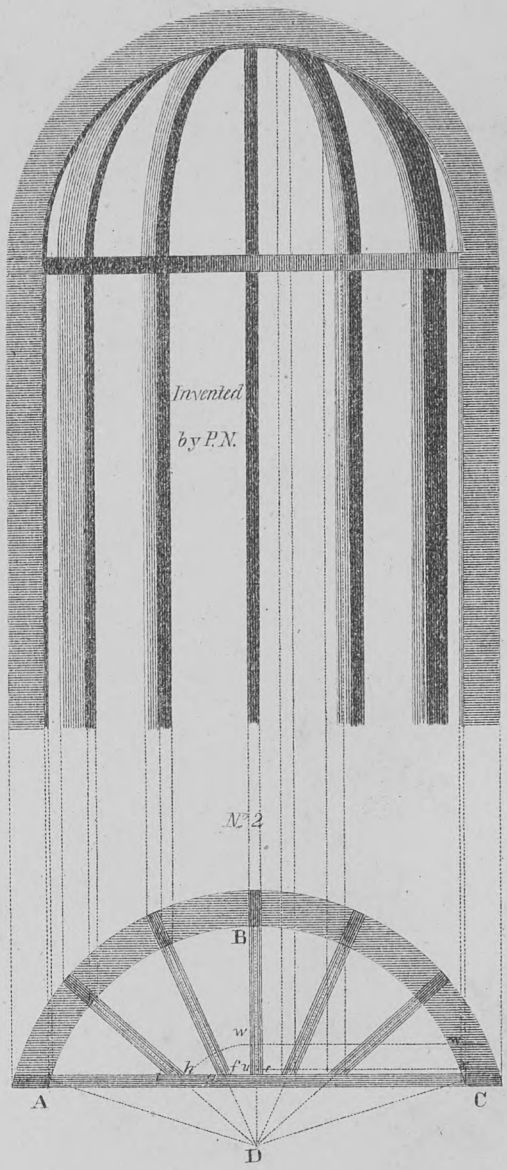


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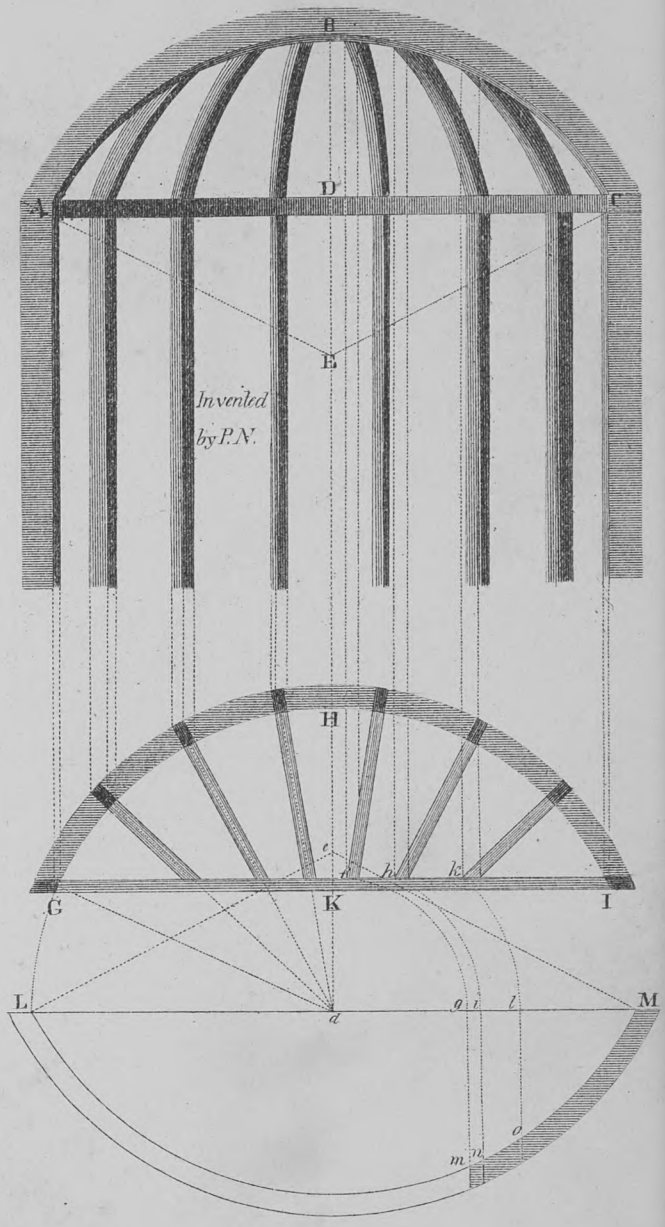


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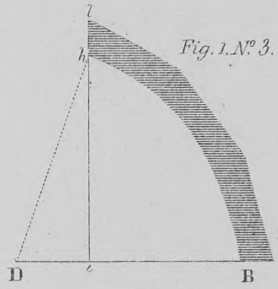


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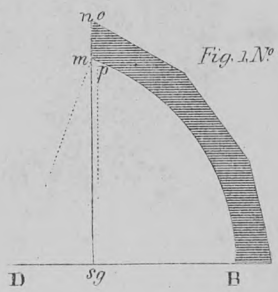
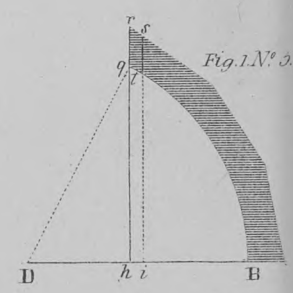


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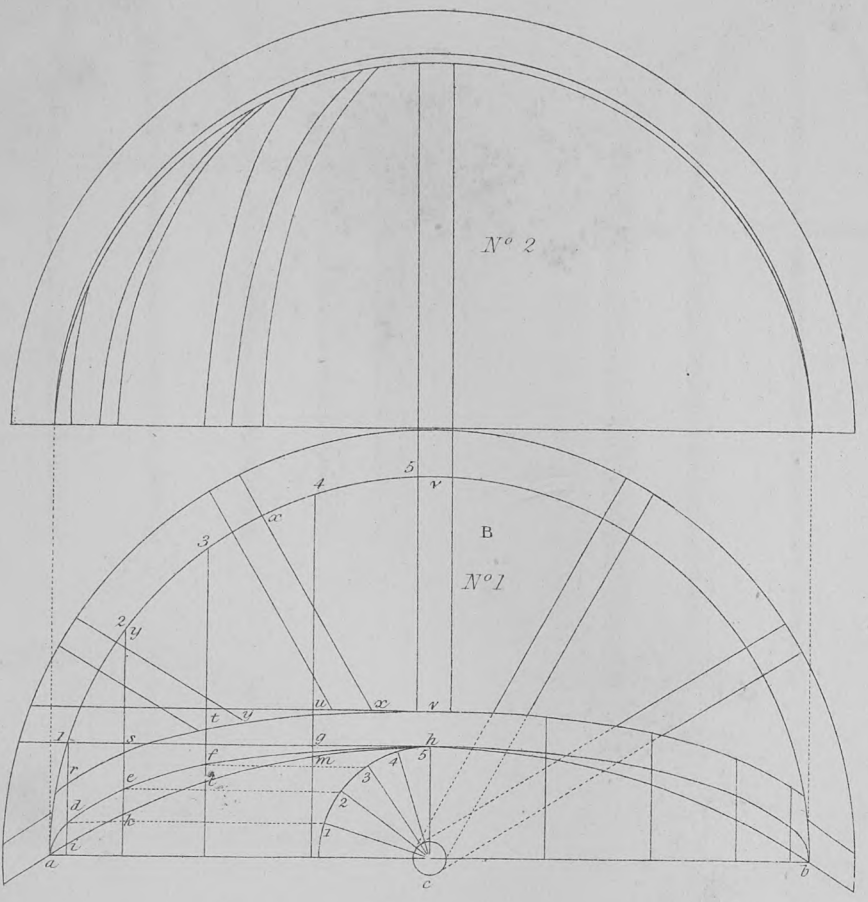


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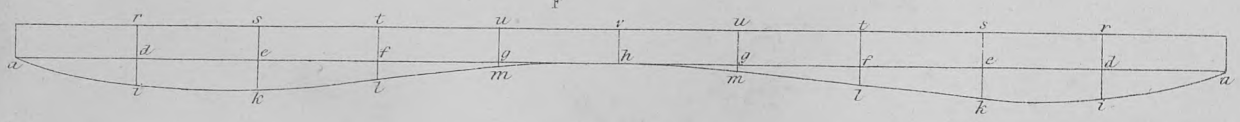
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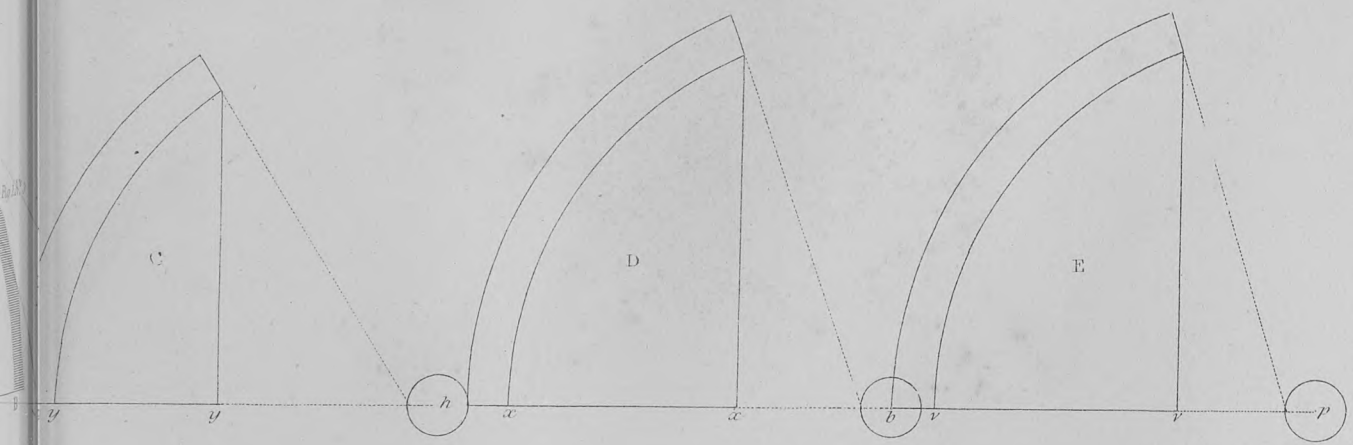
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Fig. 1



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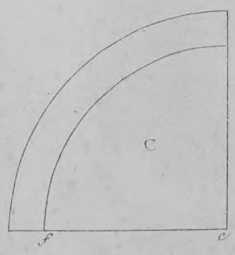


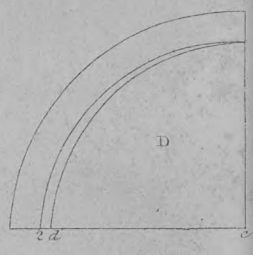
P. Nicholson.

Engraved by J. C. Buttre.

Fig. A.







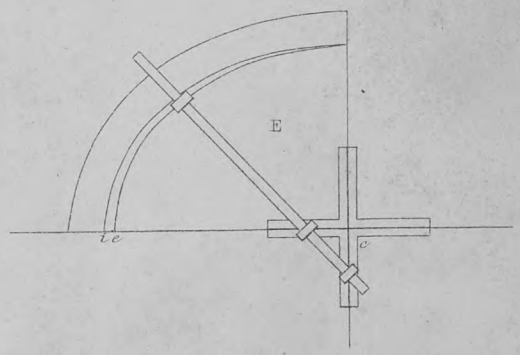
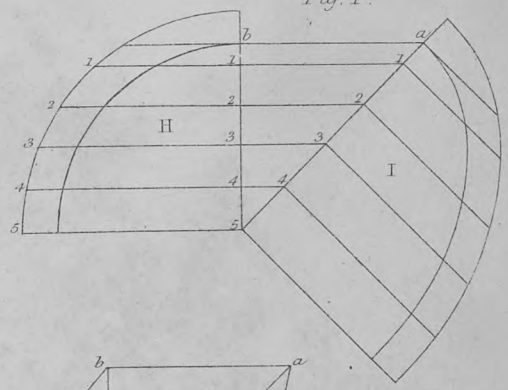
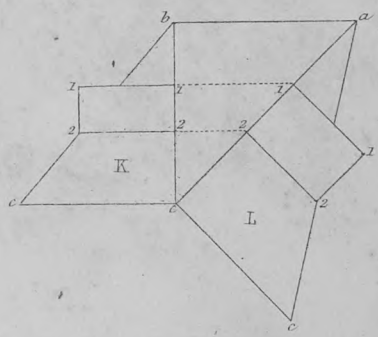
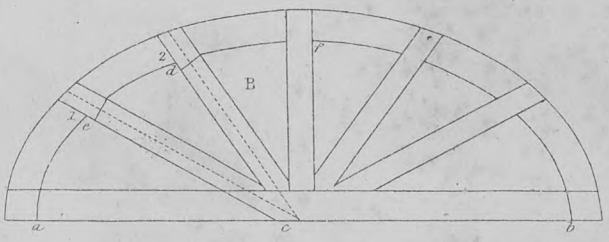


Fig. F.







Drawn by P. Nicholson.

Engraved by J.C.Bu

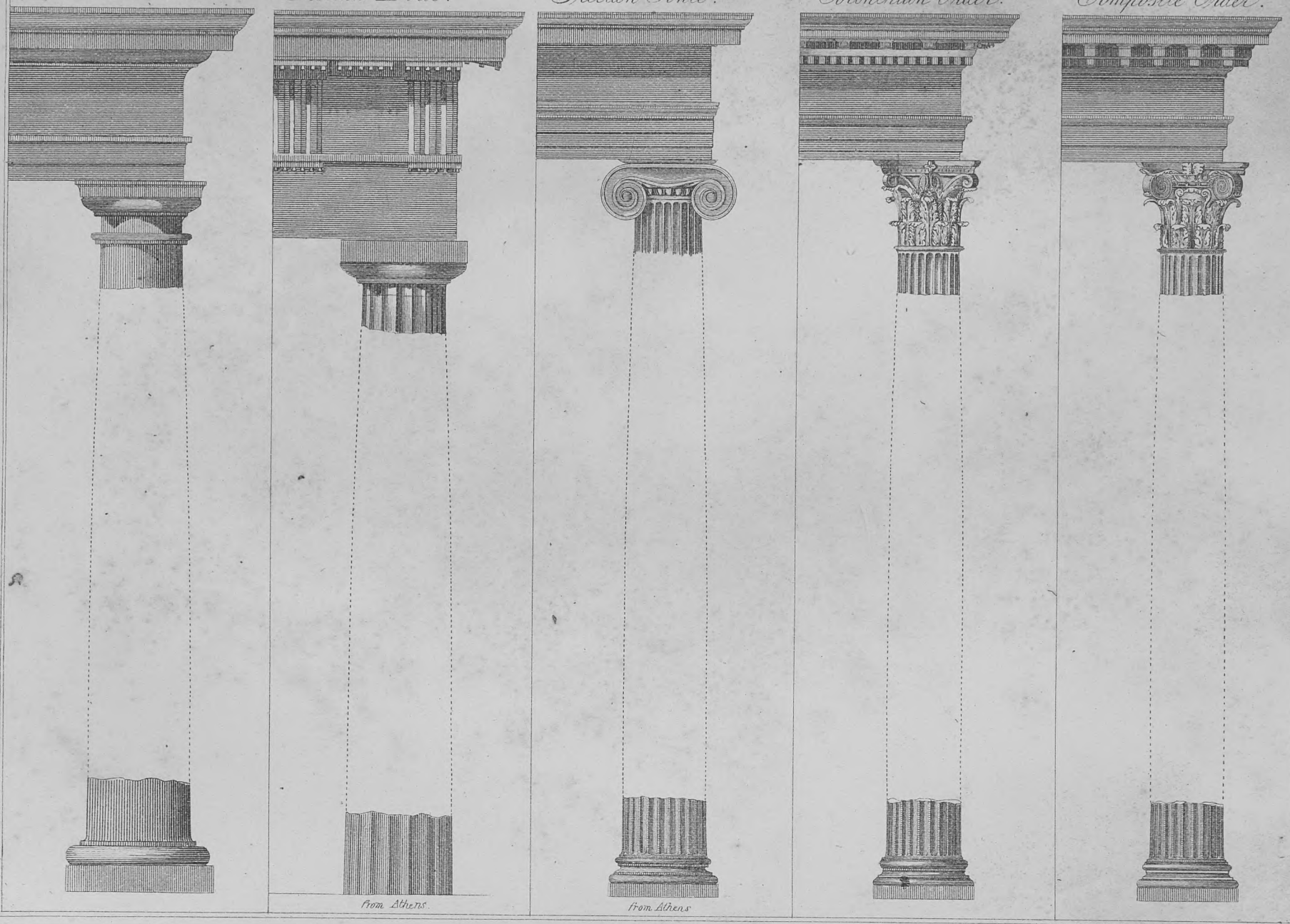

Tuscan Order.
Grecian Doric.
Grecian Ionic.
Corinthian Order.
Composite Order.
From Athens.
From Athens.
R. Thew sc.

Fig. 3.

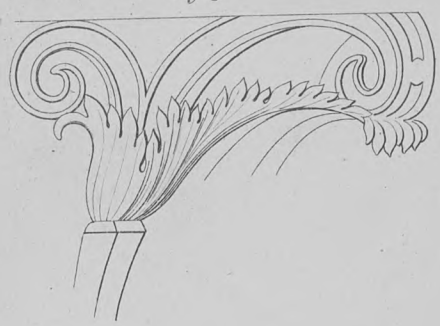


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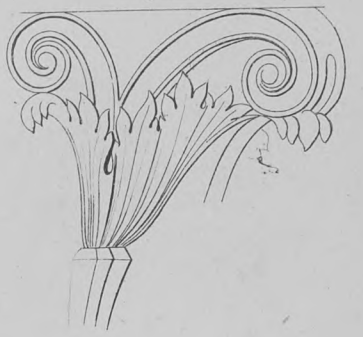


Fig. 1.



Fig. 6.

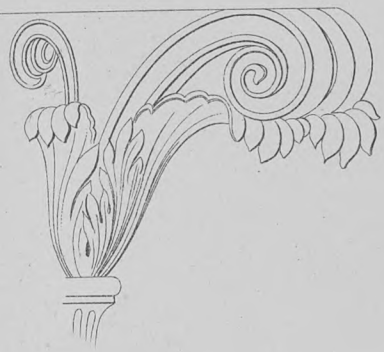


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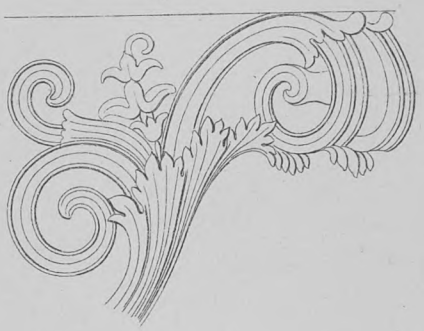


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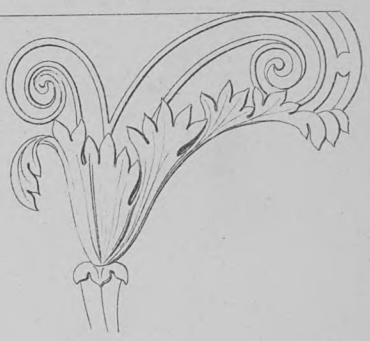


Fig. 9



Fig. 8

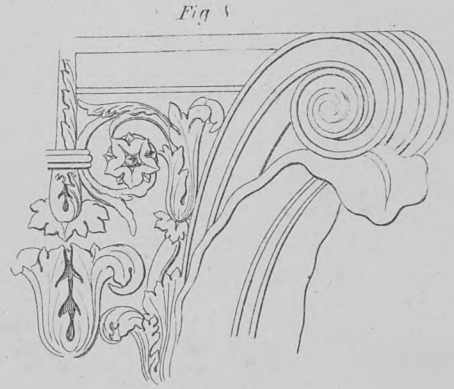


Fig. 7.



Fig. 12.

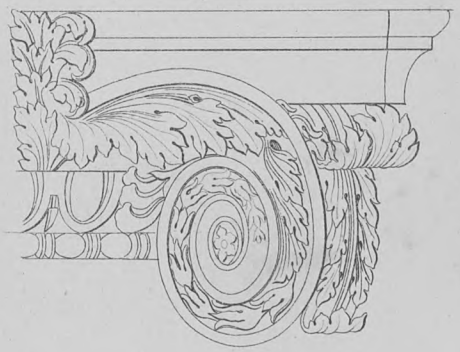


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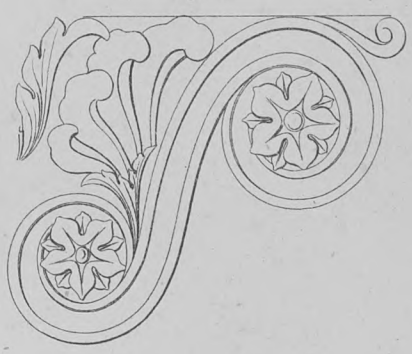
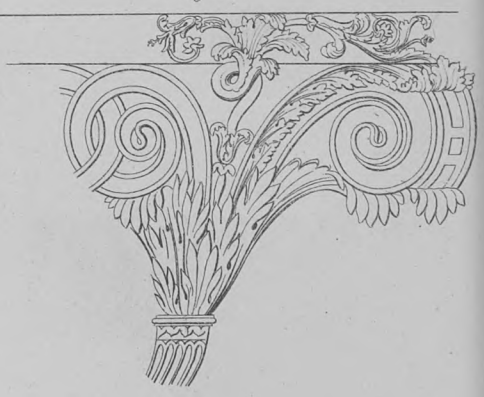


Fig. 10.



Drawn by M.A.Nicholson.

Engd by R. Thew.

OVAL.

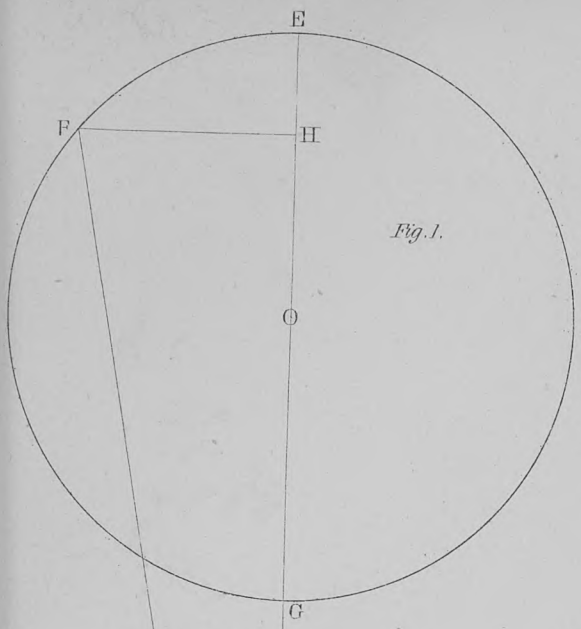


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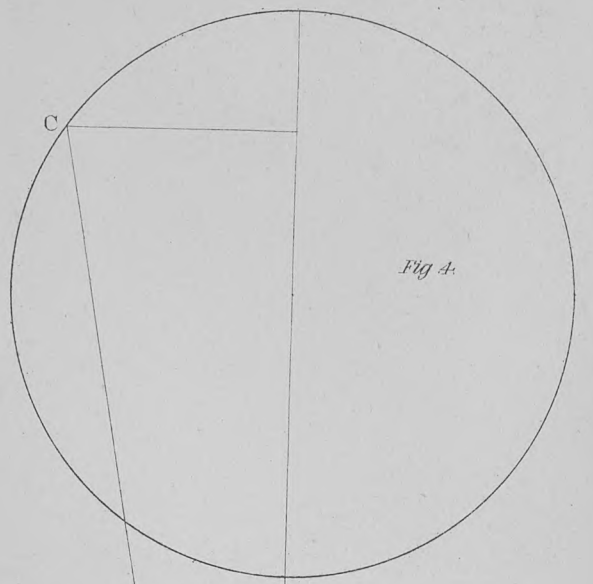
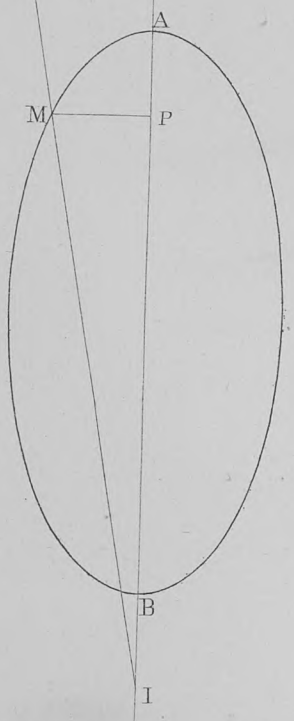
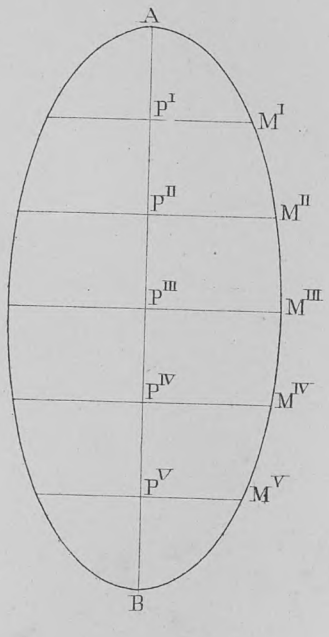


Fig 4.

Fig. 2.





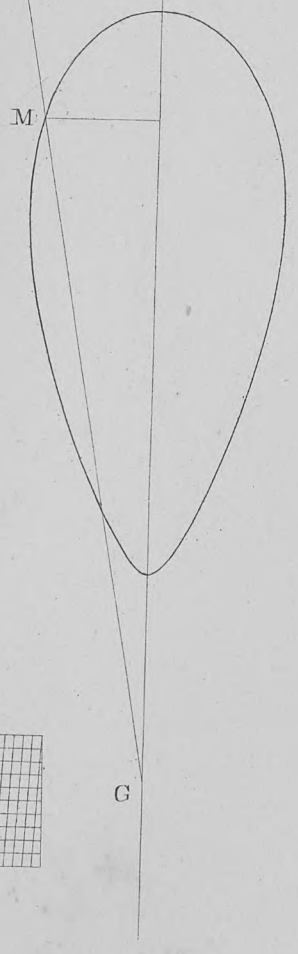
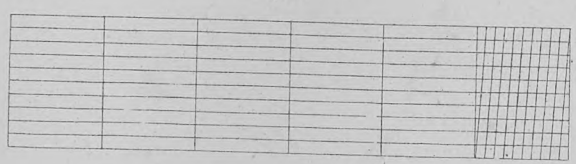


Fig. 3.



Invented by P. Nicholson.
Drawn by M.A. Nicholson.

Engraved by J.C. Buttre.

OVAL.

Fig. 5.

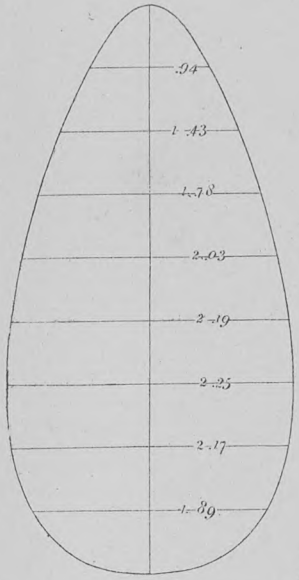


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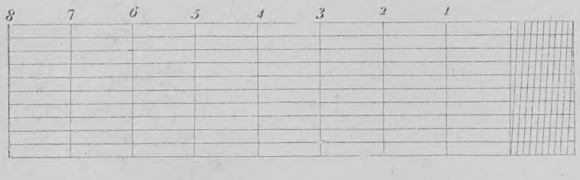


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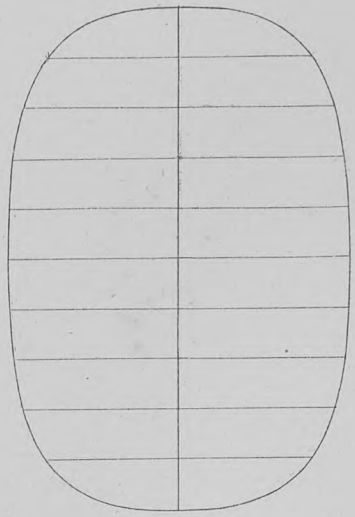


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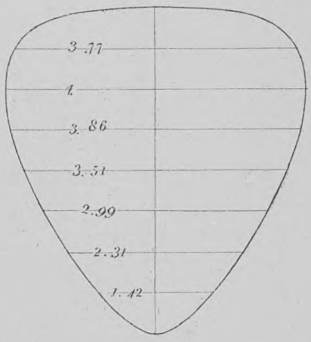


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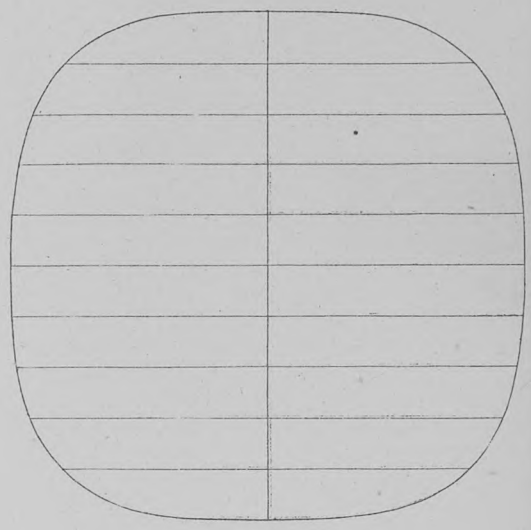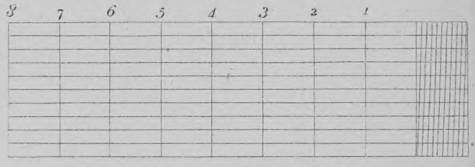


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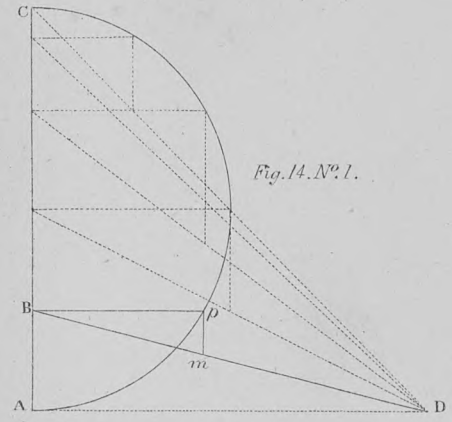
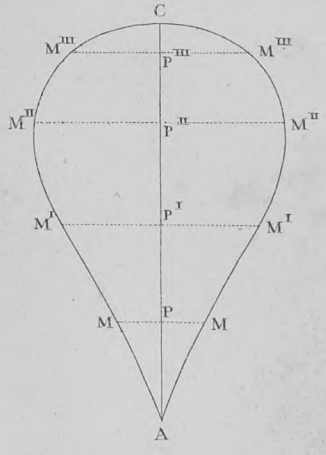


Fig. 14. Nº 1.

Fig. 14. Nº 2.



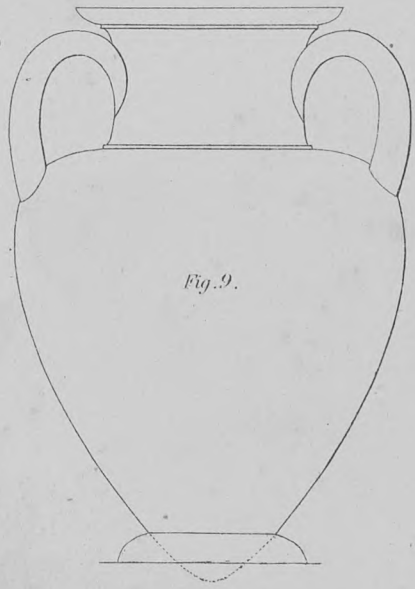


Fig. 9.



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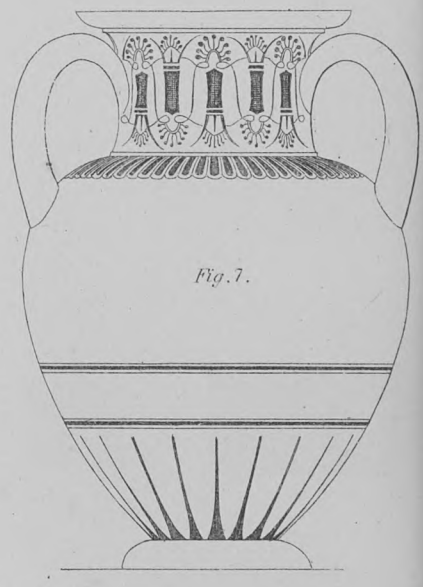


Fig. 7.

Invented by P. Nicholson.
Drawn by M.A. Nicholson.

Engraved by J.C. Buttre.

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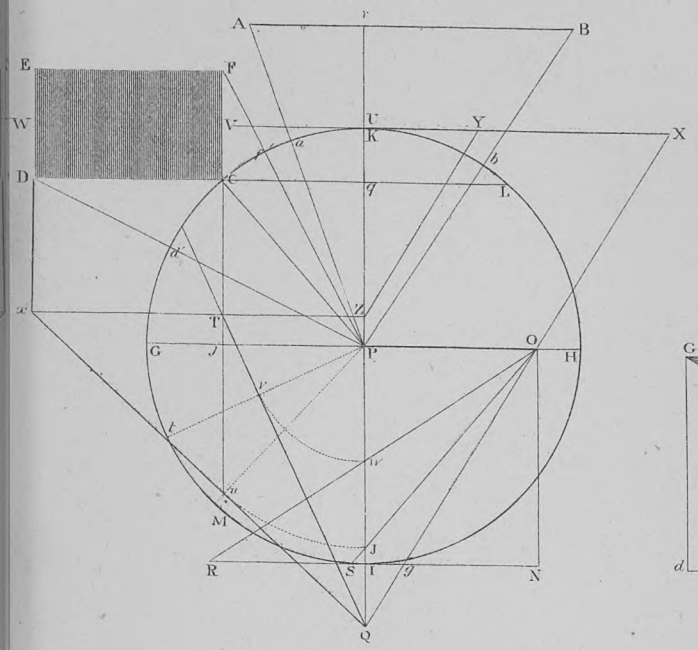


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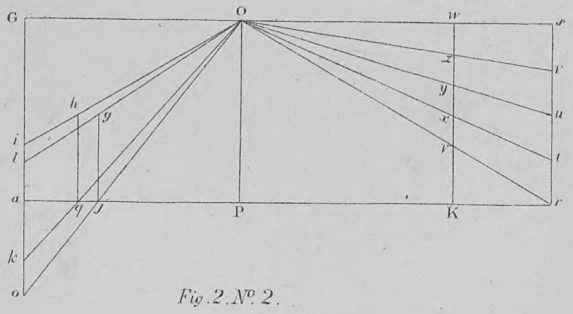


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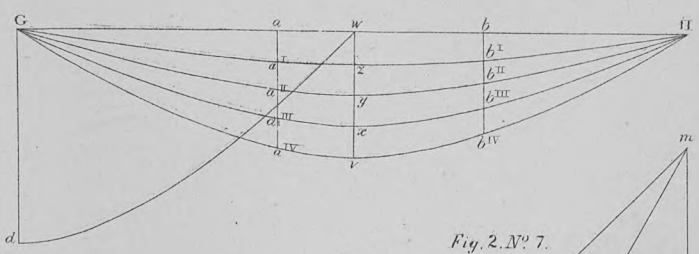


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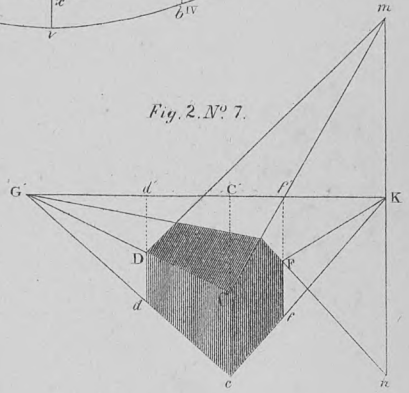


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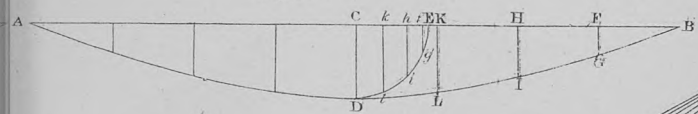


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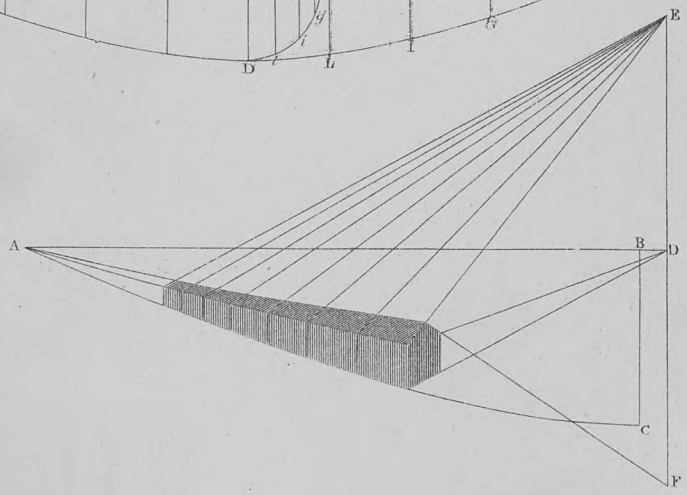


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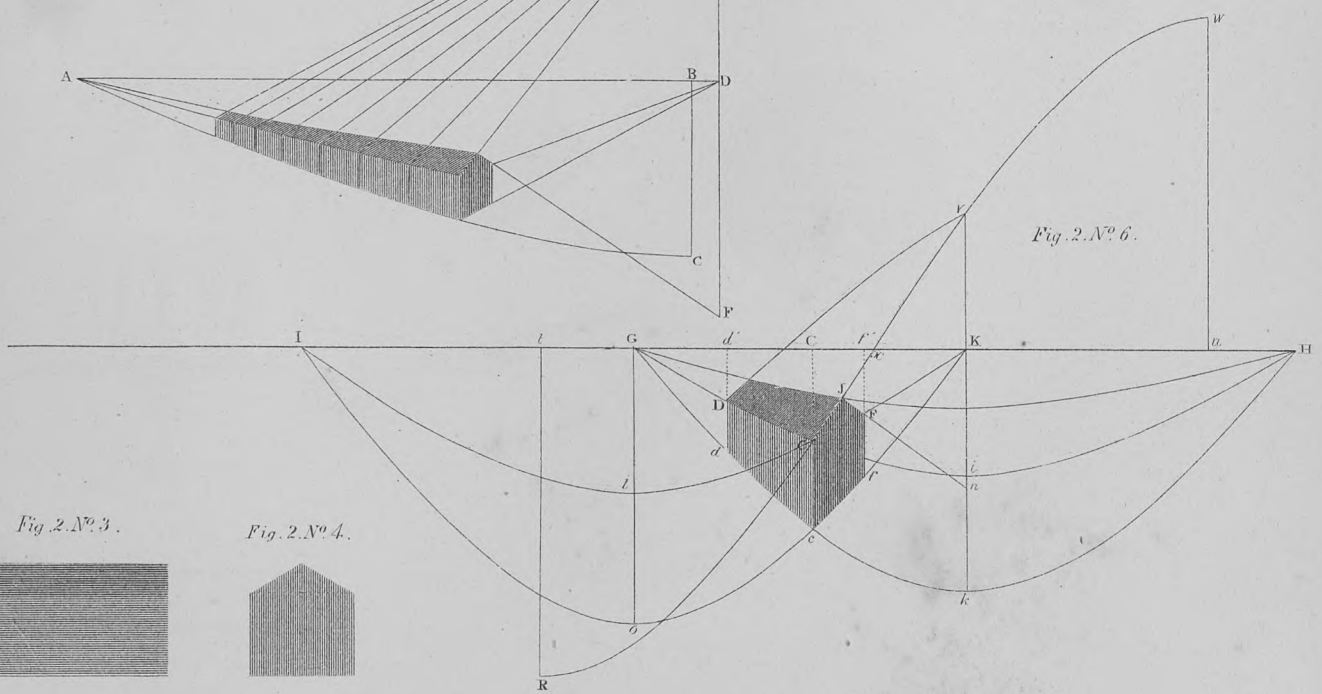


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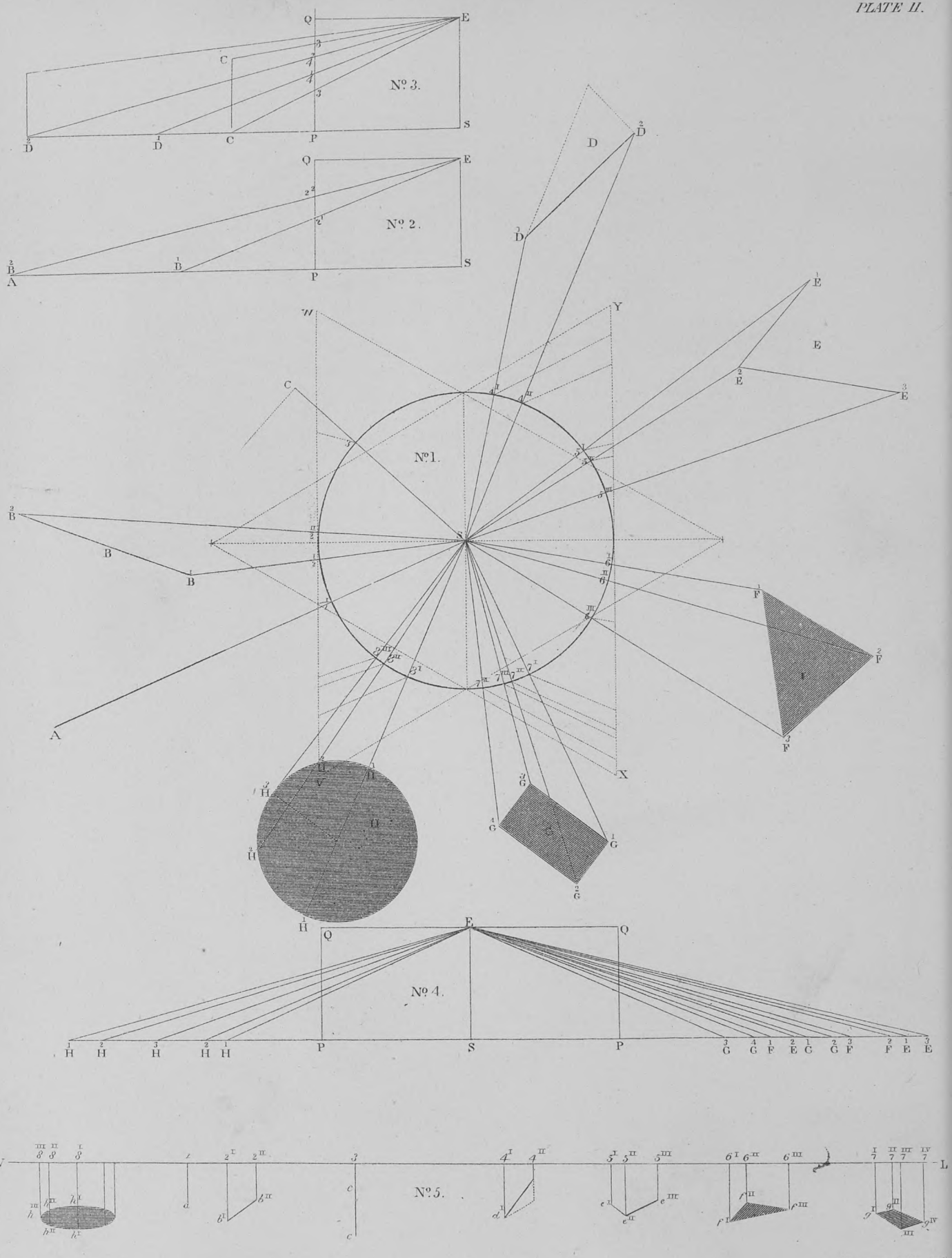


Fig. 2. N°. 4.

...aled by P. Nicholson.

Engraved by J. C. Buttre.

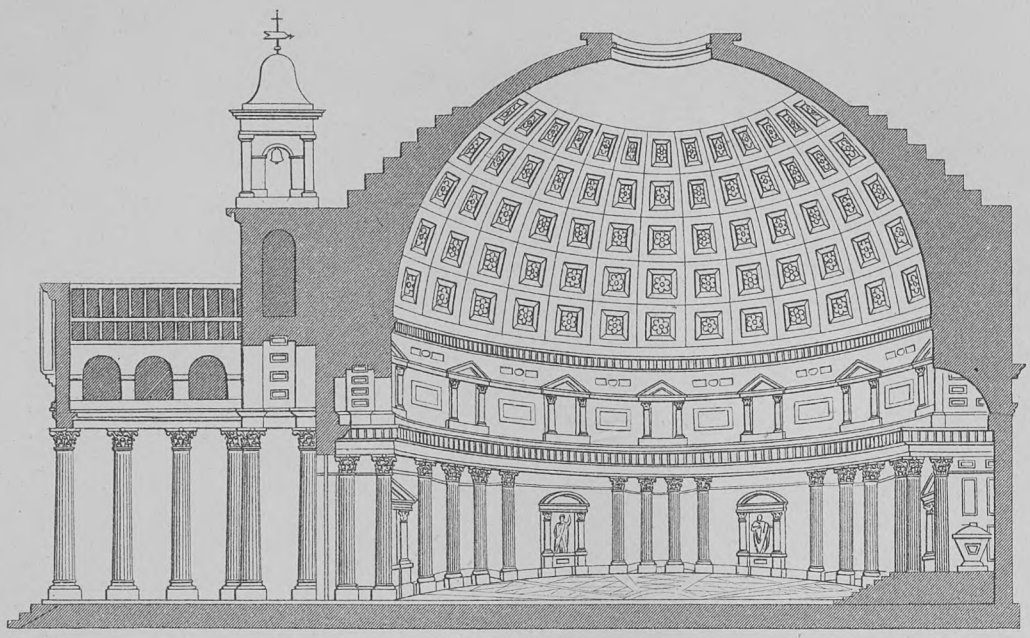
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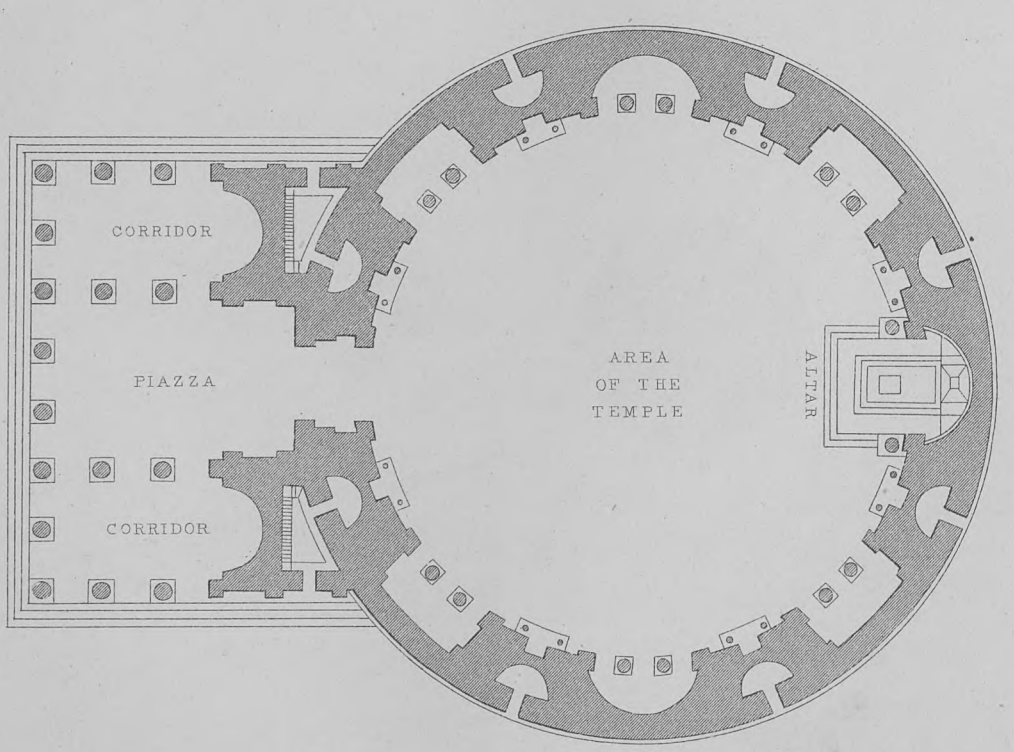
Invented by P. Nicholson.

Engraved by J.C. B[illegible]

PLAN AND SECTION OF THE HEATHEN PANTHEON AT ROME.



PERSPECTIVE SECTION.



GENERAL PLAN OF THE TEMPLE

R. Brown Archt.

R. Thew. Sc.

PAVEMENT.

Fig. 1.

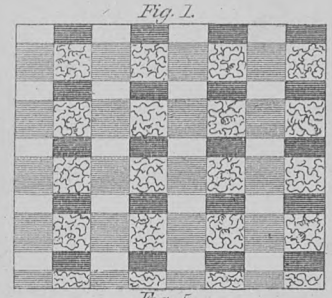


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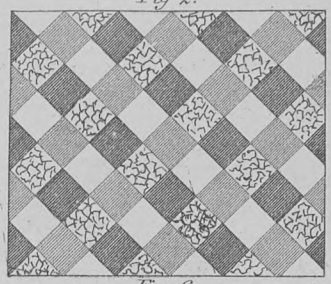


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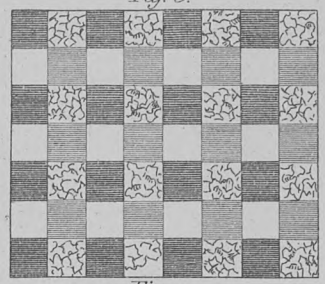


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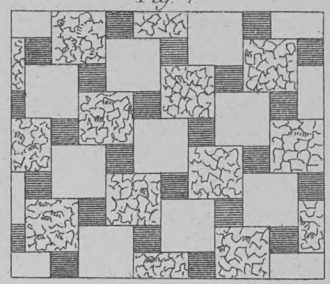


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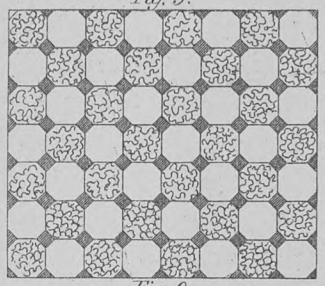


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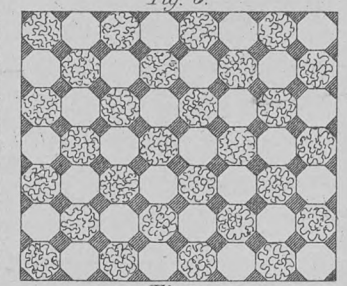


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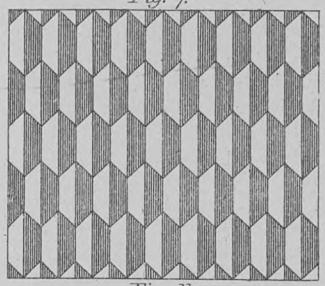


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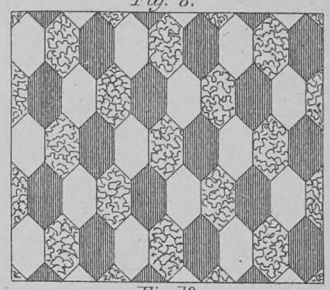


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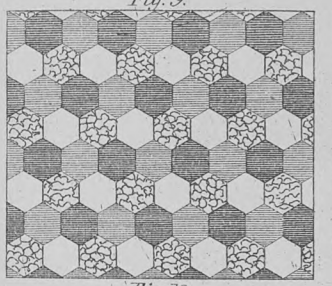


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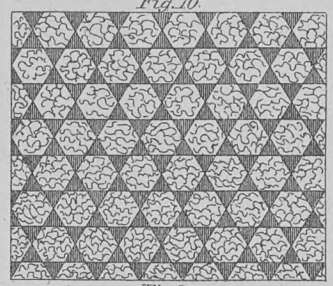


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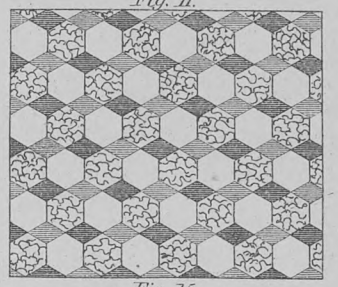


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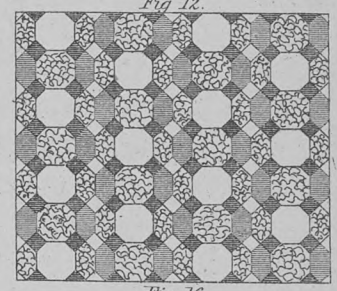


Fig. 13.

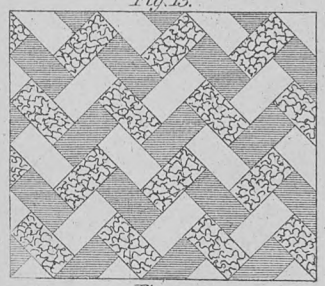


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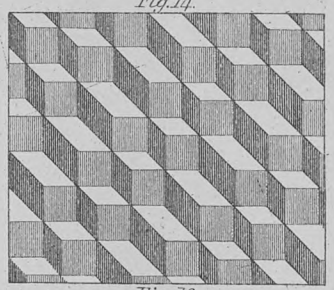


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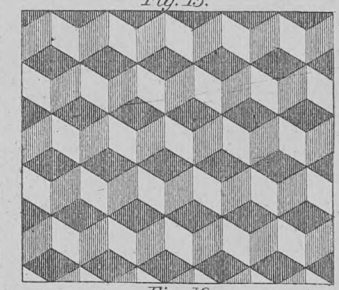


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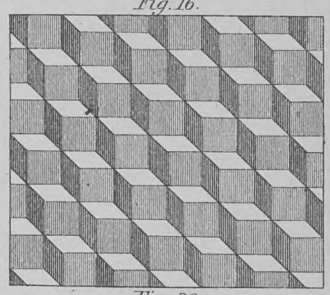


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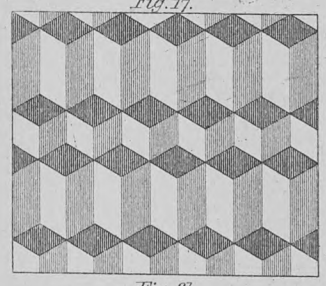


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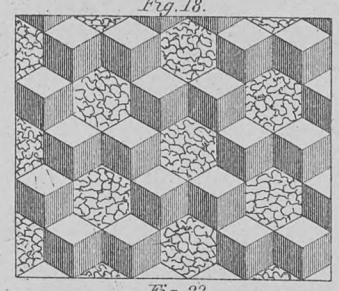


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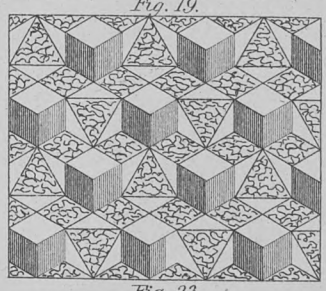


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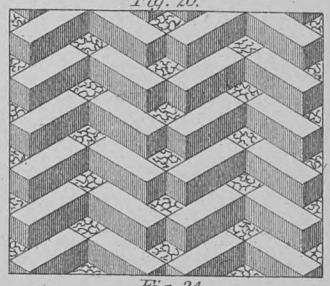


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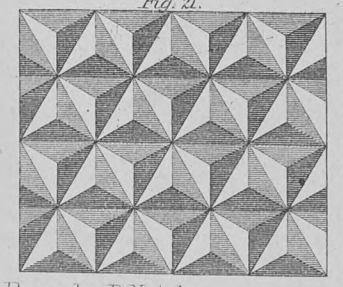


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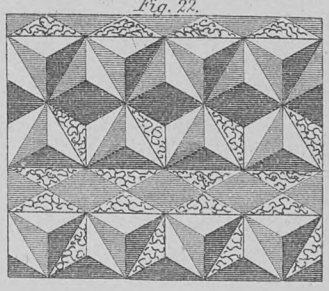


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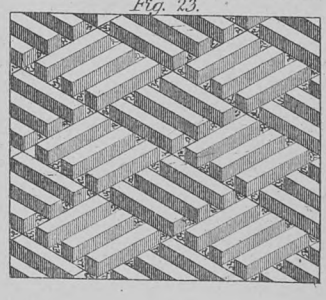
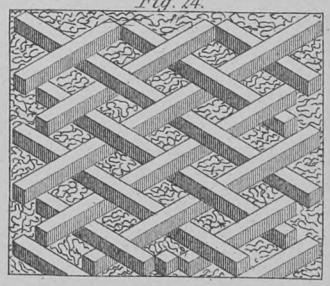


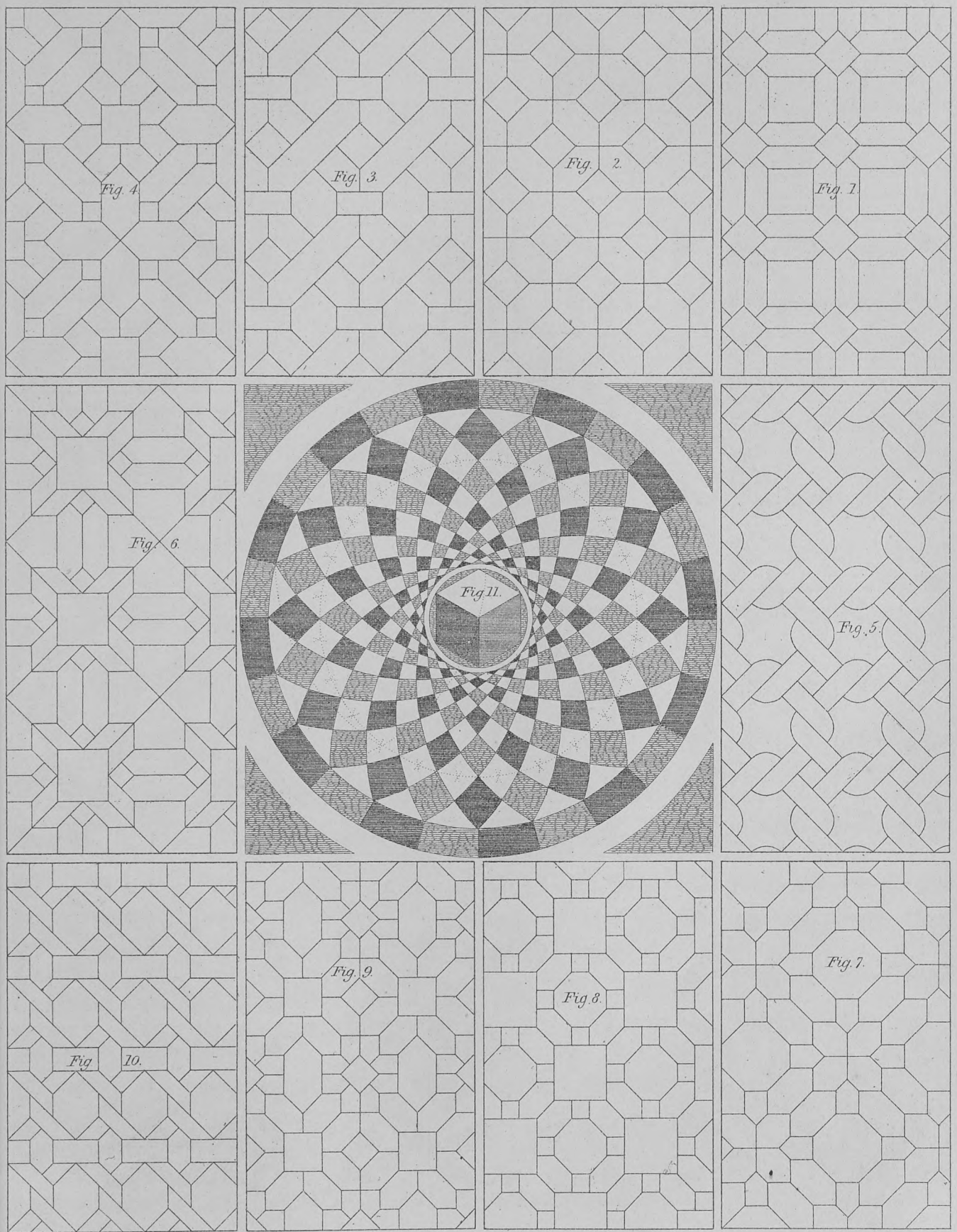
Fig. 24.



Drawn by P. Nicholson.

Engd by R. Thew.

PAVEMENT.



Drawn by M.A.Nicholson

Engd by R. Thew.

Fig. 1.

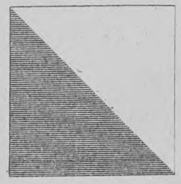


Fig. 2



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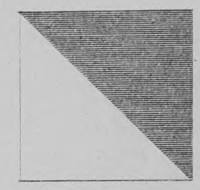


Fig. 4.



Fig. 5

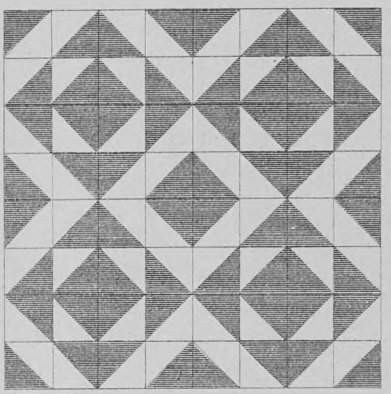


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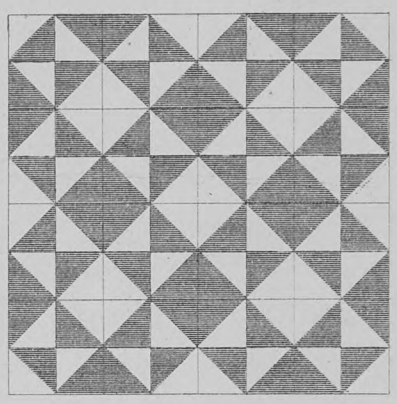


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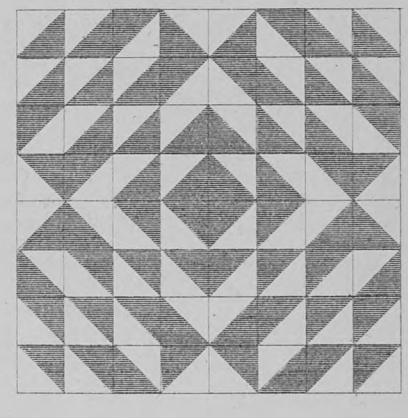


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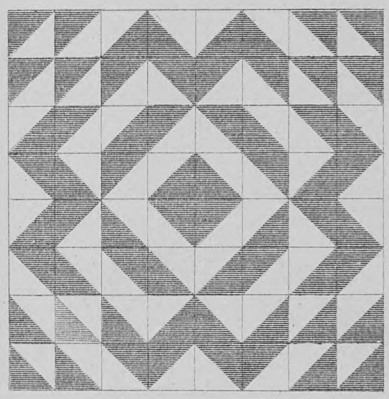


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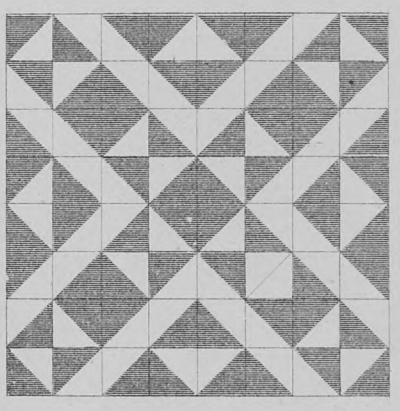


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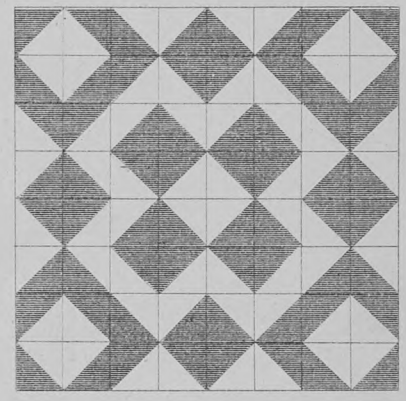


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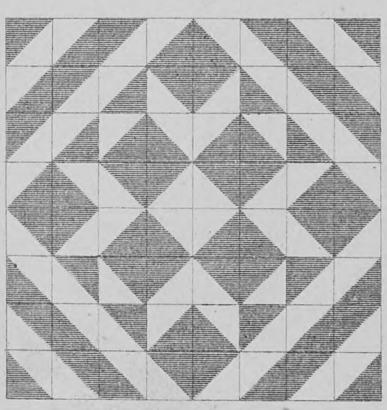


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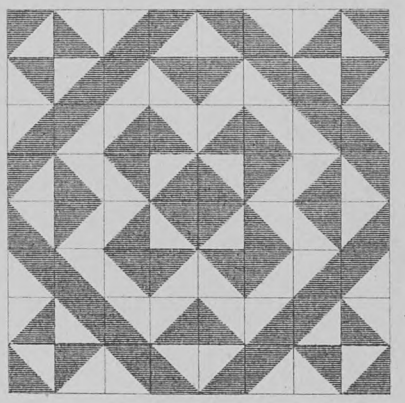
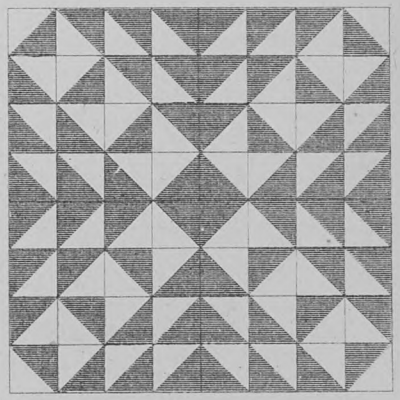


Fig. 13.



Drawn by M.A.Nicholson.

Eng by R Thew.

PENDENTIVE CRADLING.

Fig. 1.

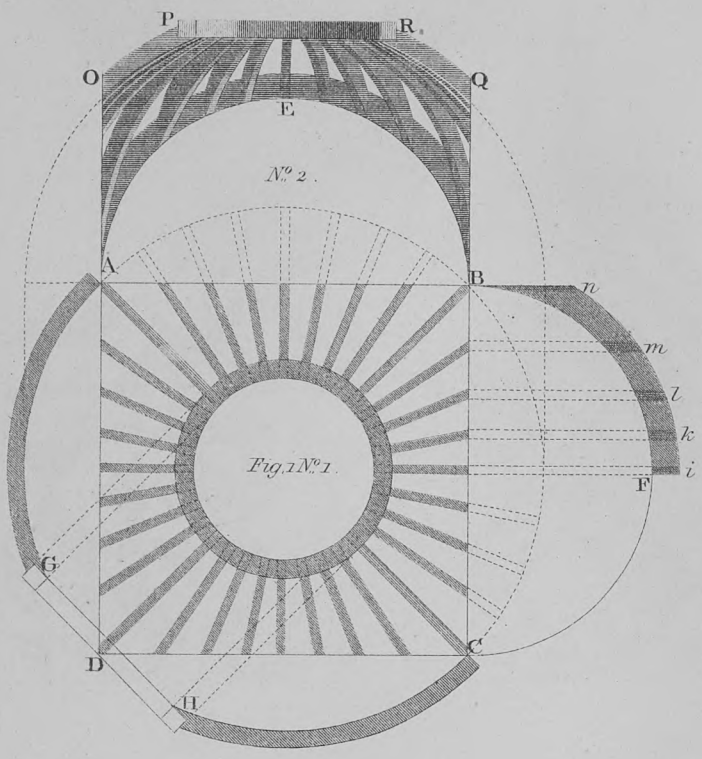
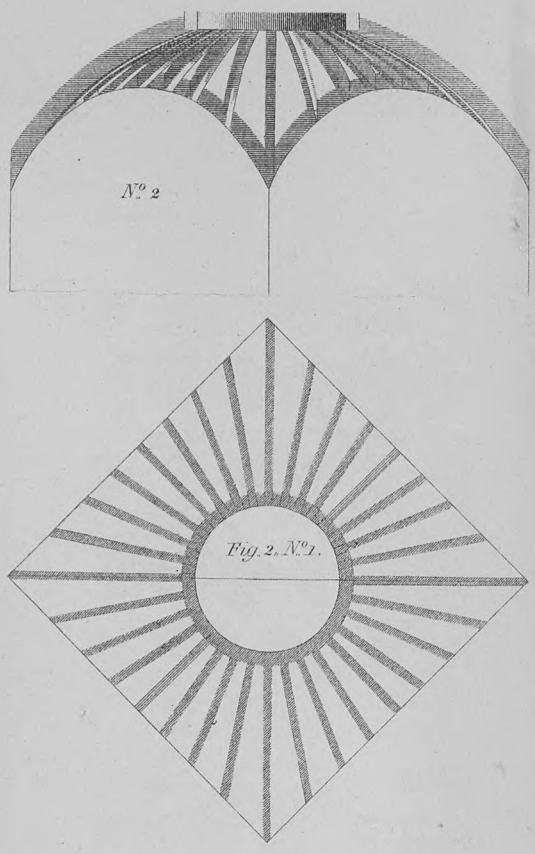
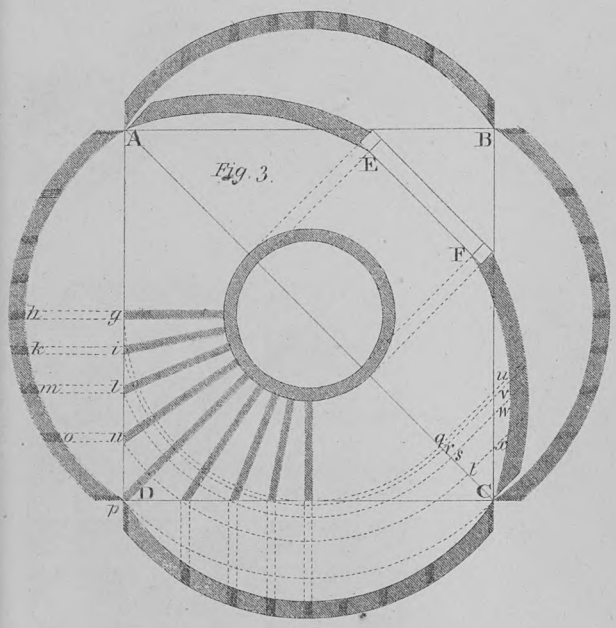
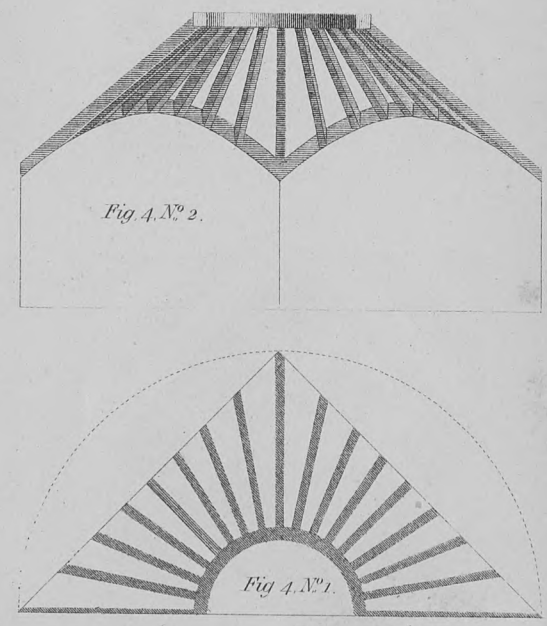


Fig. 2.







Invented & Drawn by P. Nicholson.

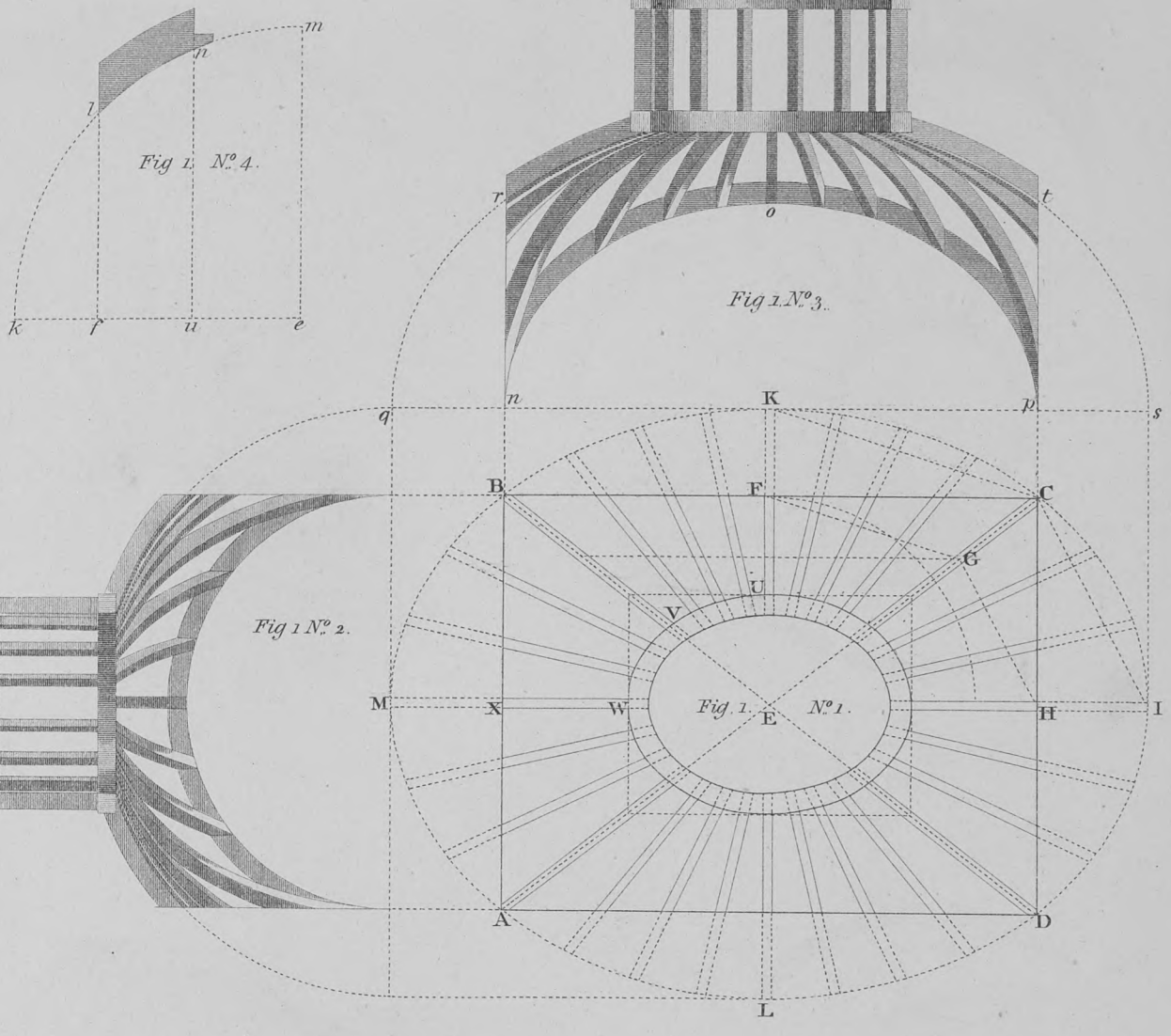
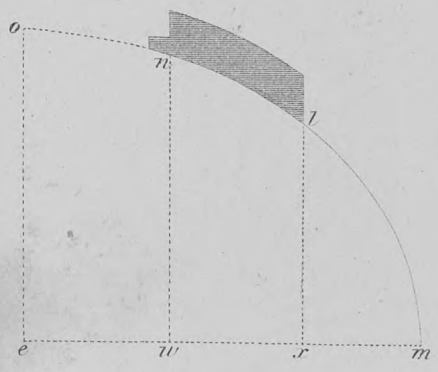


Fig 1. N.º 4.

Fig 1 N.º 3.

Fig 1 N.º 2.

Fig. 1. N.º 1.



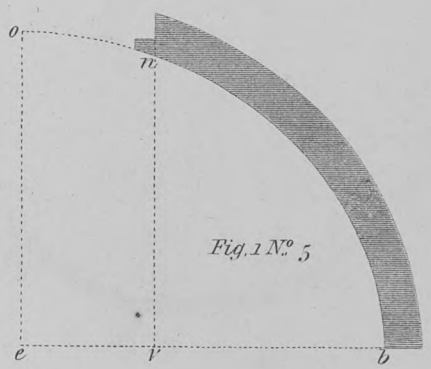


Fig. 1 N.º 5

Invented & drawn by P Nicholson

Engd. by R. Thew.

PERSPECTIVE PLATE 1.

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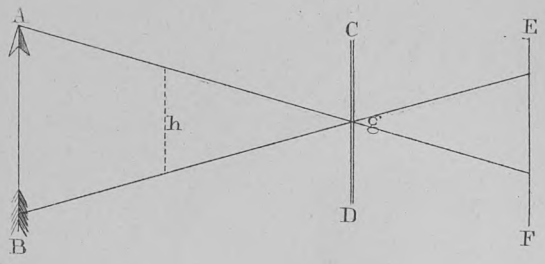


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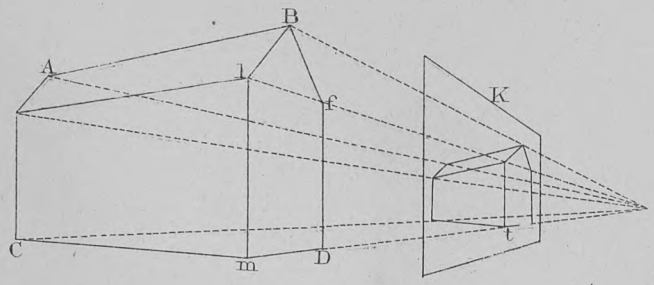


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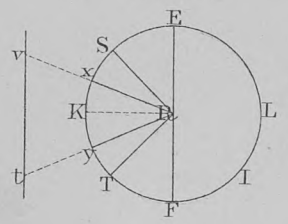


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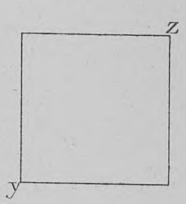


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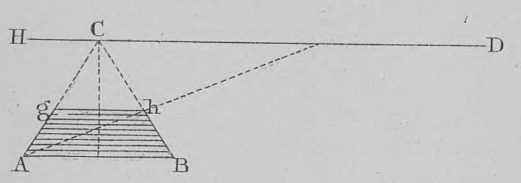


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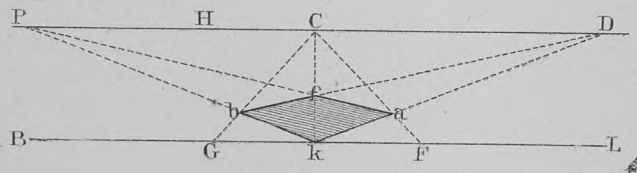


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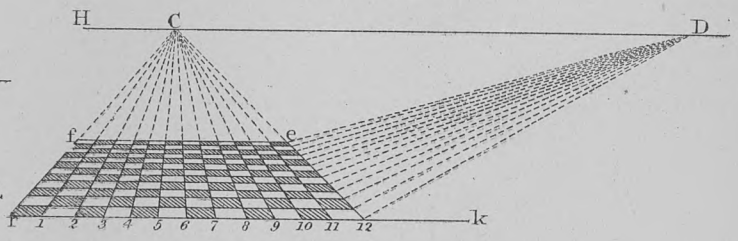


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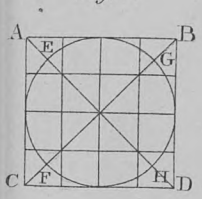


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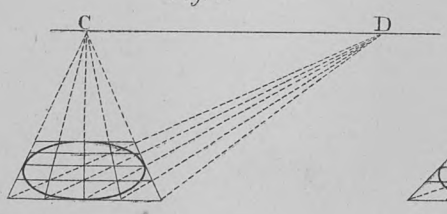


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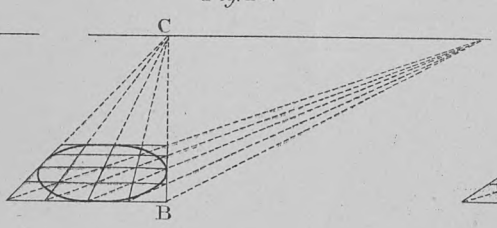
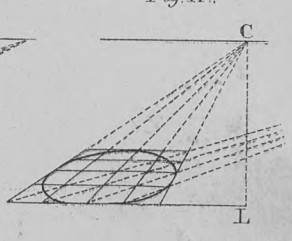


Fig. 11.



D Howman del.

Engd by R. Thew.

Fig. 12.

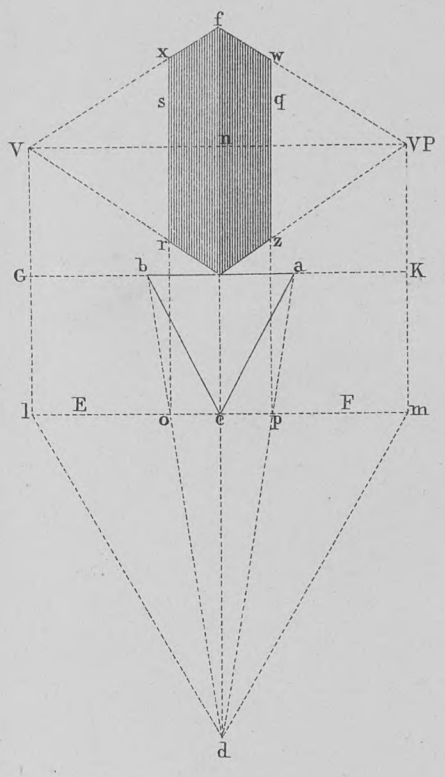


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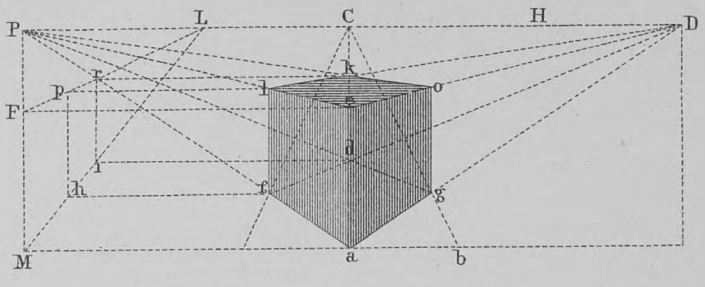


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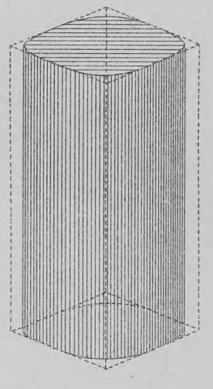


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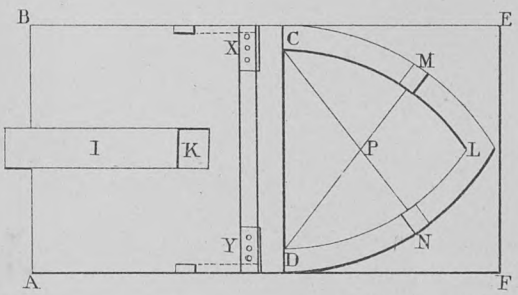
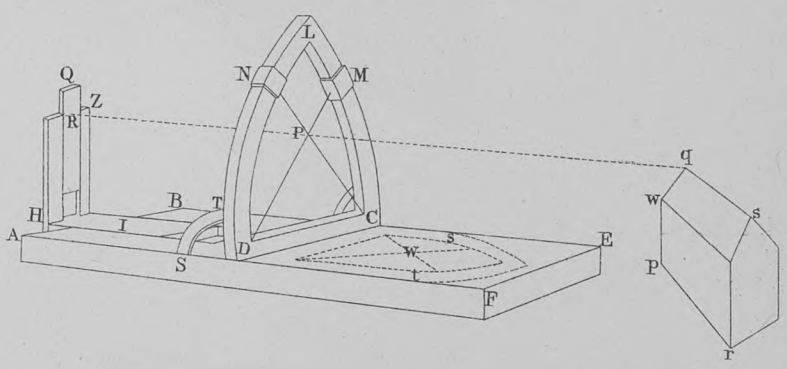


Fig. 16.



E. D. Howman. del.

Eng. by R. Thew.

Fig. 1.

Fig. 2.

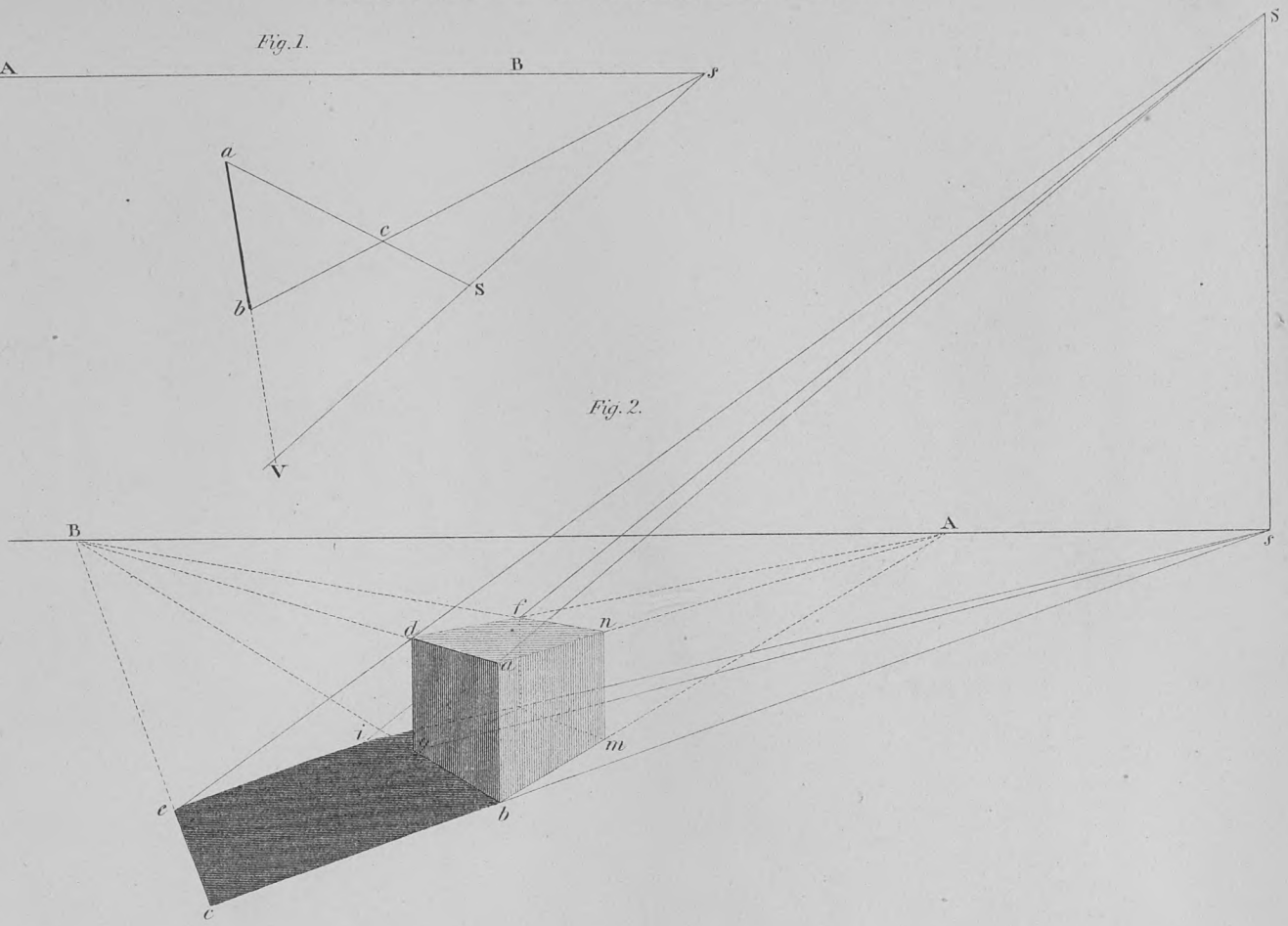


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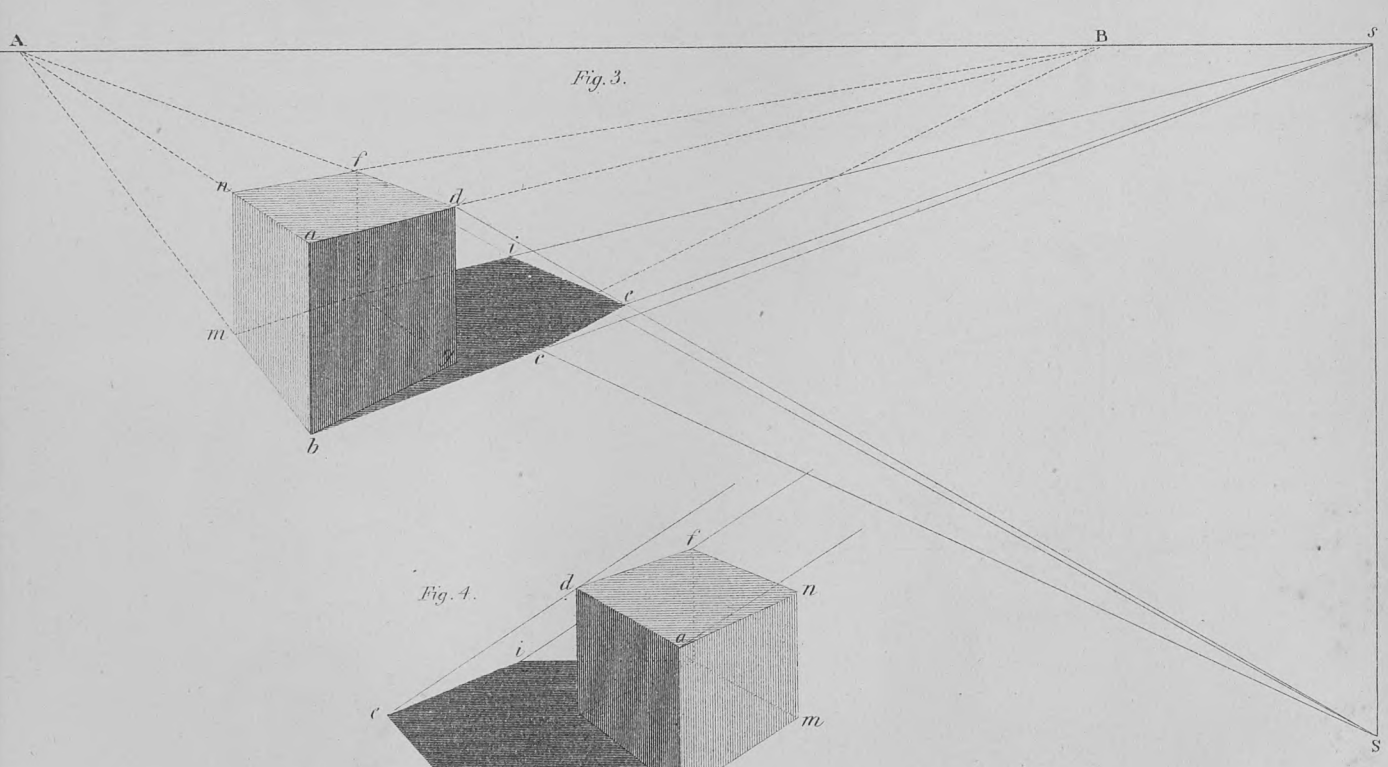
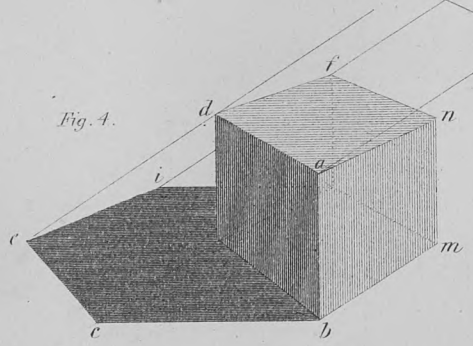


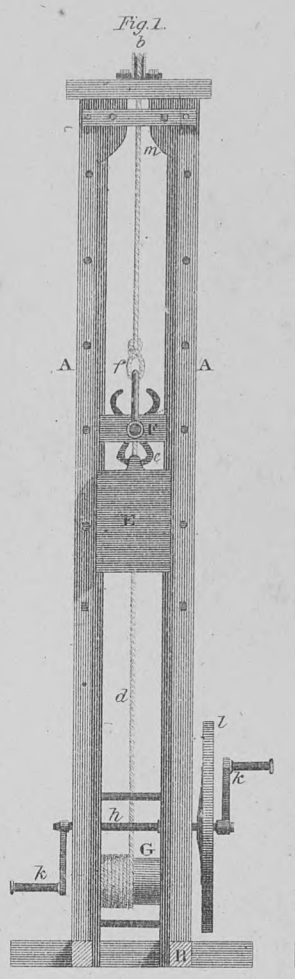
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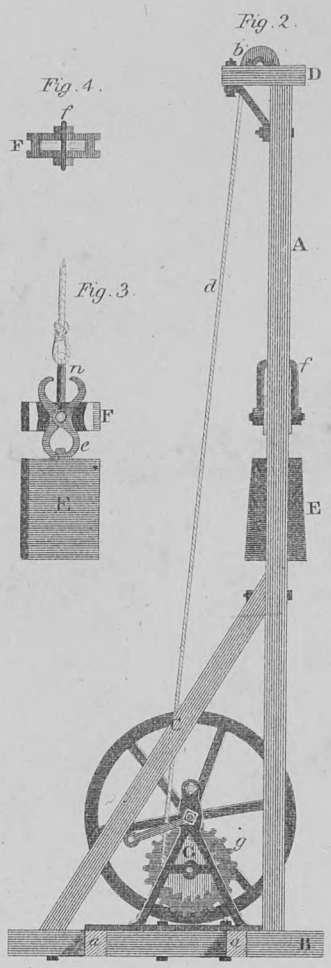


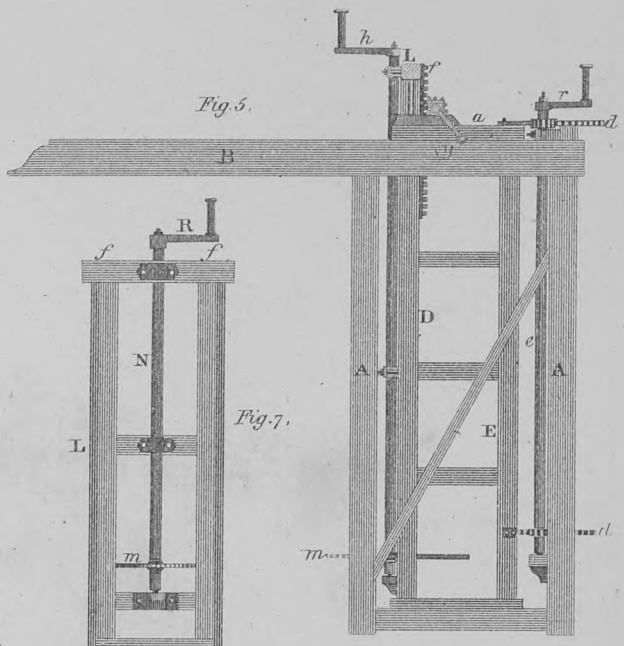
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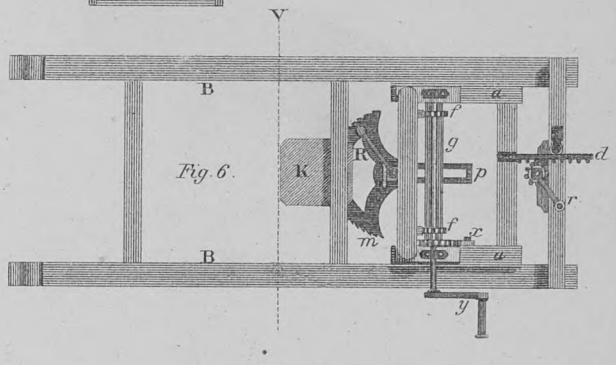
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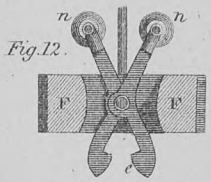
PILE DRIVING MACHINE.

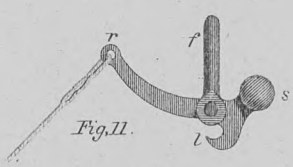




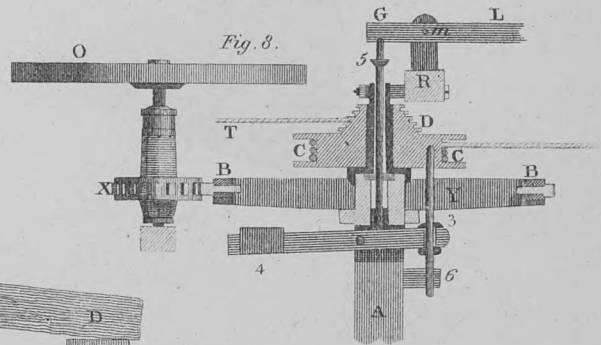




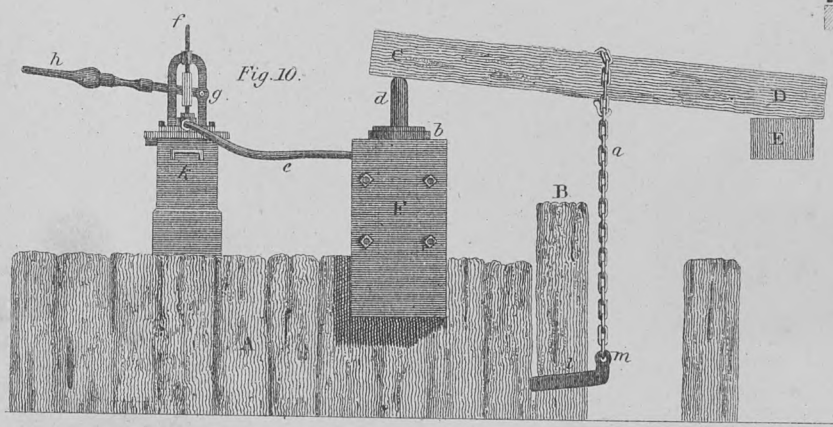


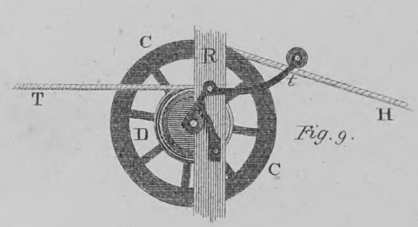


Section of Valoues Pile Engine.



Mr Bramahs Machine for Drawing Piles out of the Ground.





PLANING MACHINE.

Mr BRAMAHs PLANING MACHINE.

Fig 7

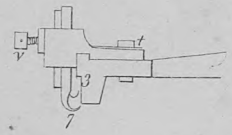
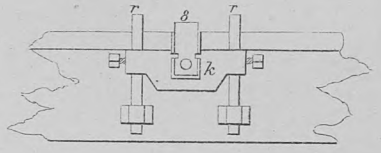


Fig. 6.



Plan

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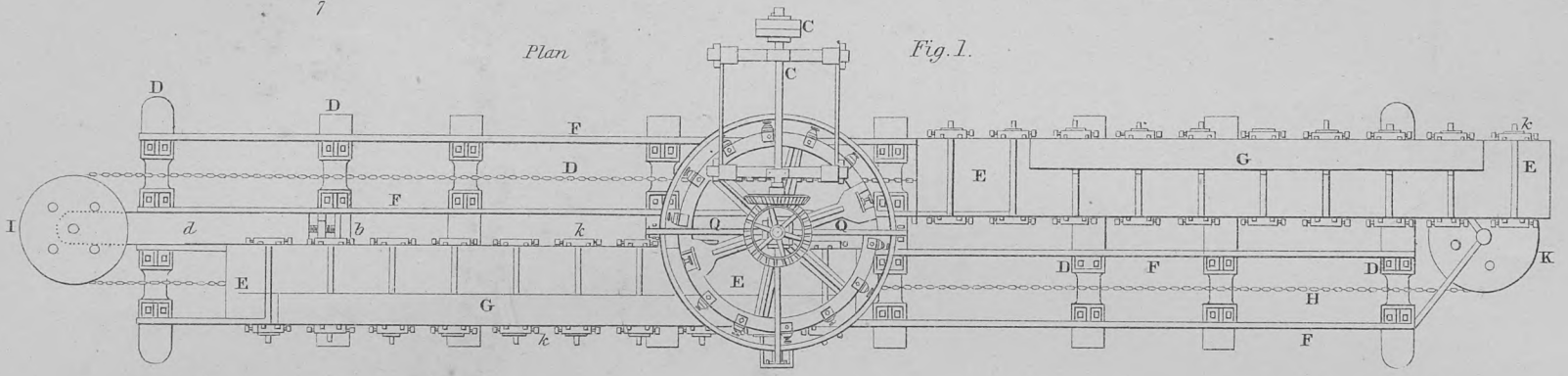


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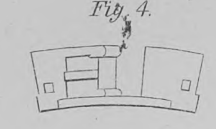
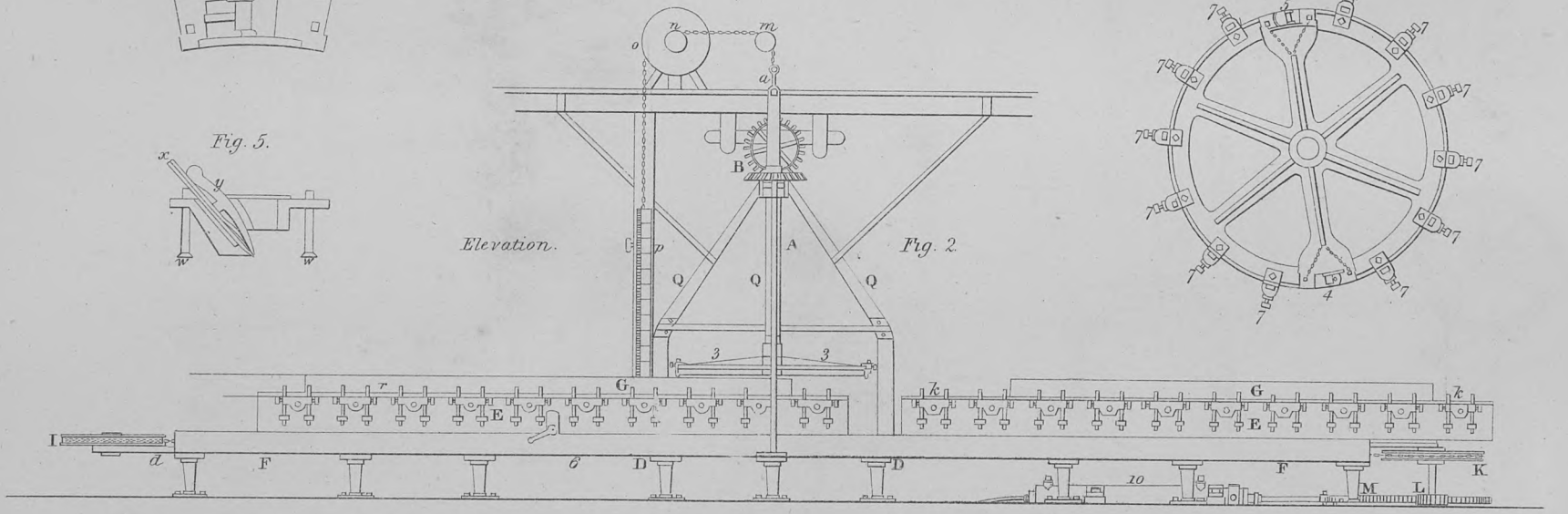


Fig. 3.

Fig. 5.

Elevation.

Fig. 2.



304 – VOL. 2

PLANING MACHINE.

Mr BRAMAH's PLANING MACHINE.

Cross Section.

Fig. 9

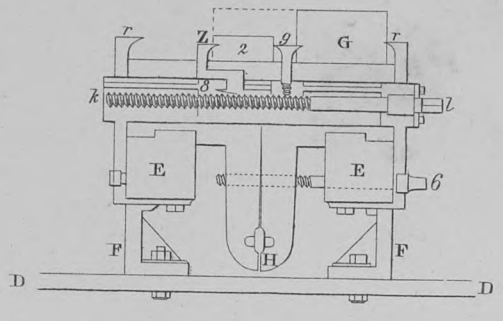
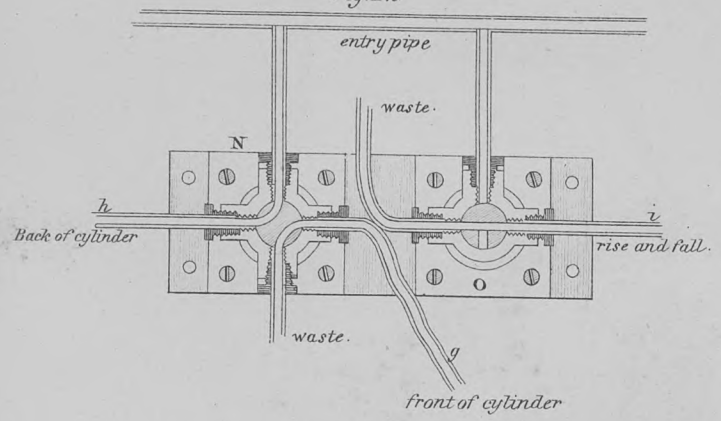
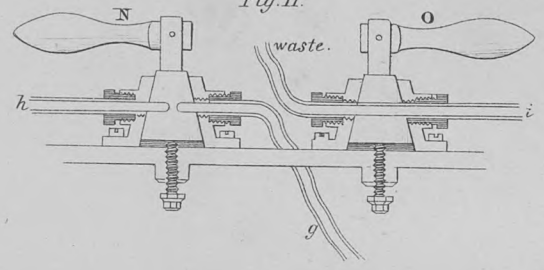


Fig. 12.



Cocks

Fig. 11.



Cylinder.

Fig. 10.

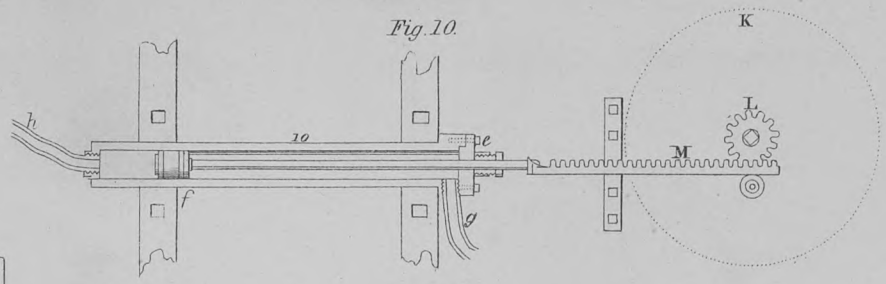
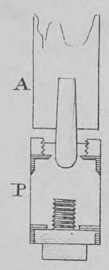
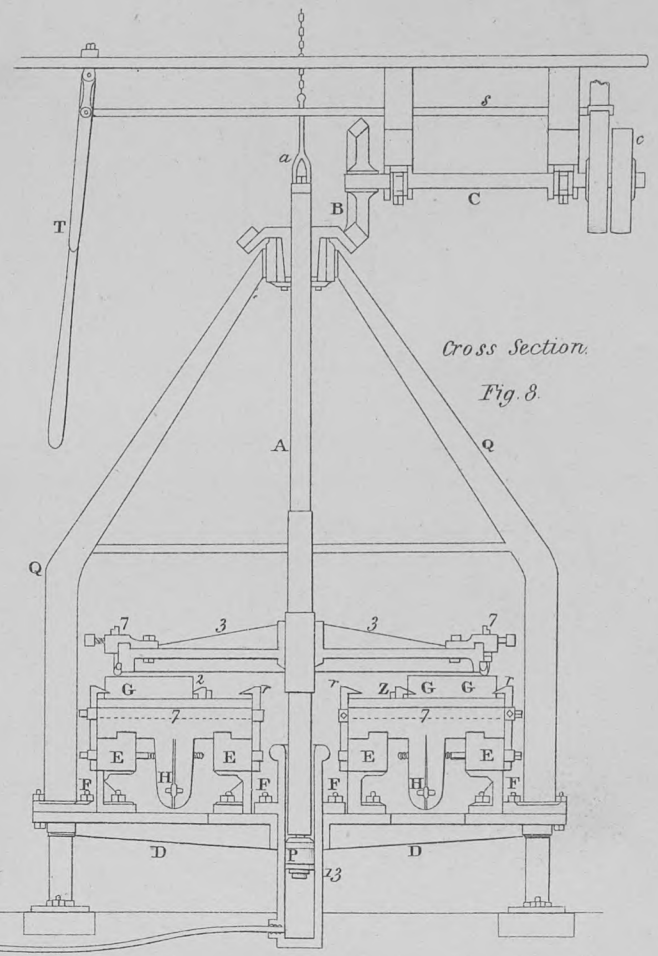




Fig. 13.





Cross Section.

Fig. 8.

304 – VOL. 2

Drawn by P. Nicholson

Engd by B. Thew

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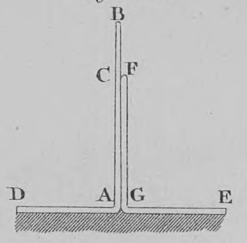


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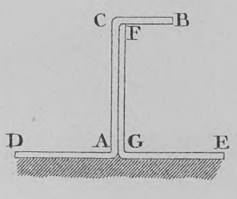


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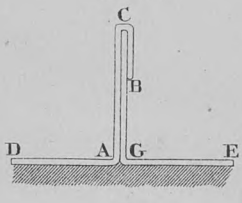


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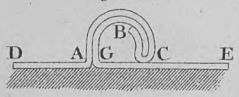


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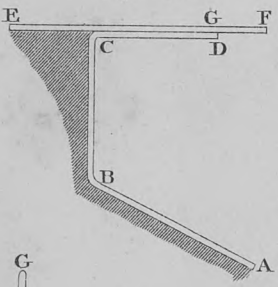


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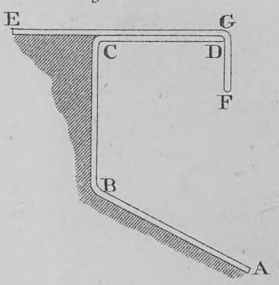


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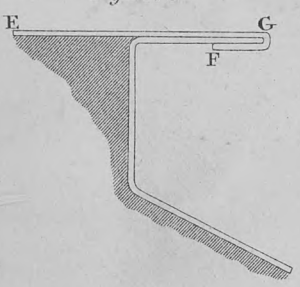


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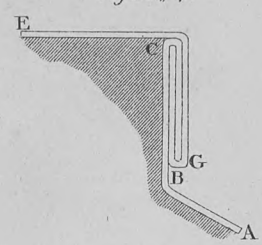


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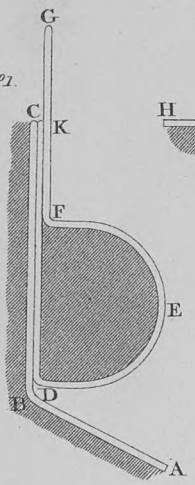


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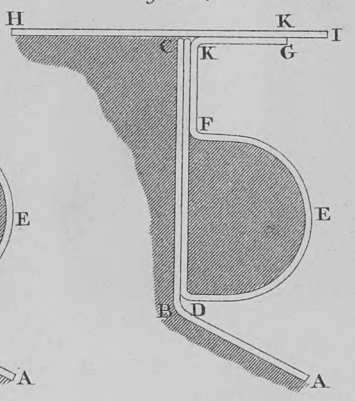


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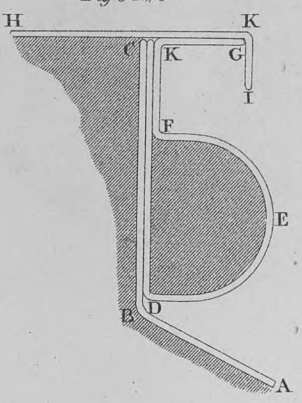


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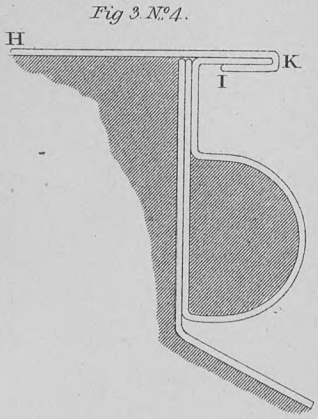


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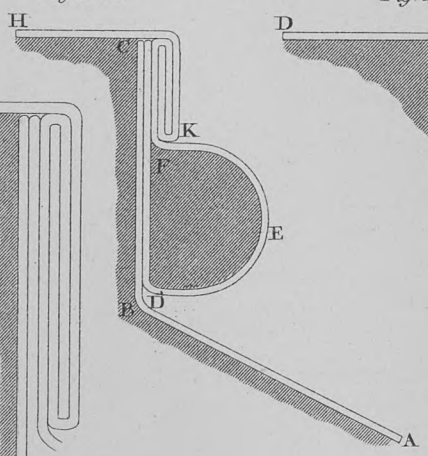


Fig 3 N.º 6.



Fig 4.

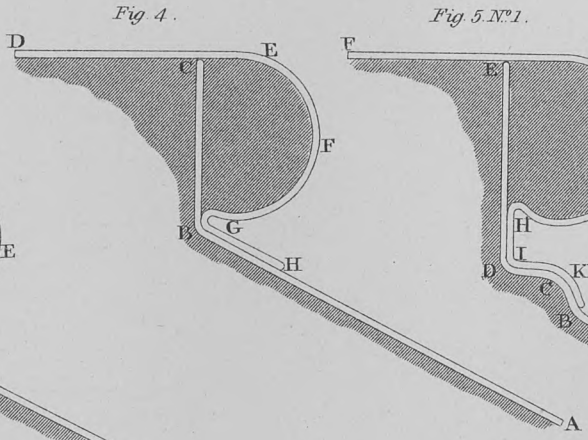
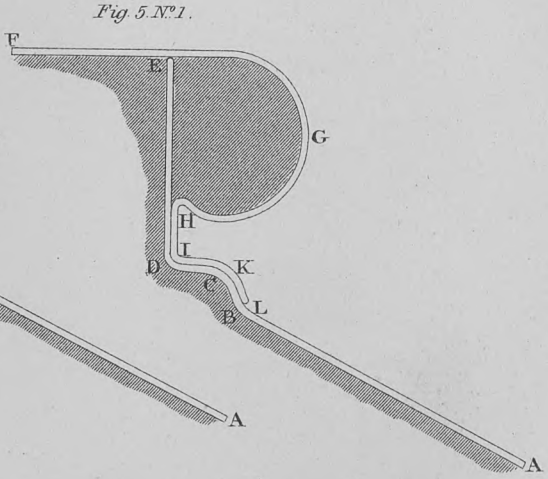


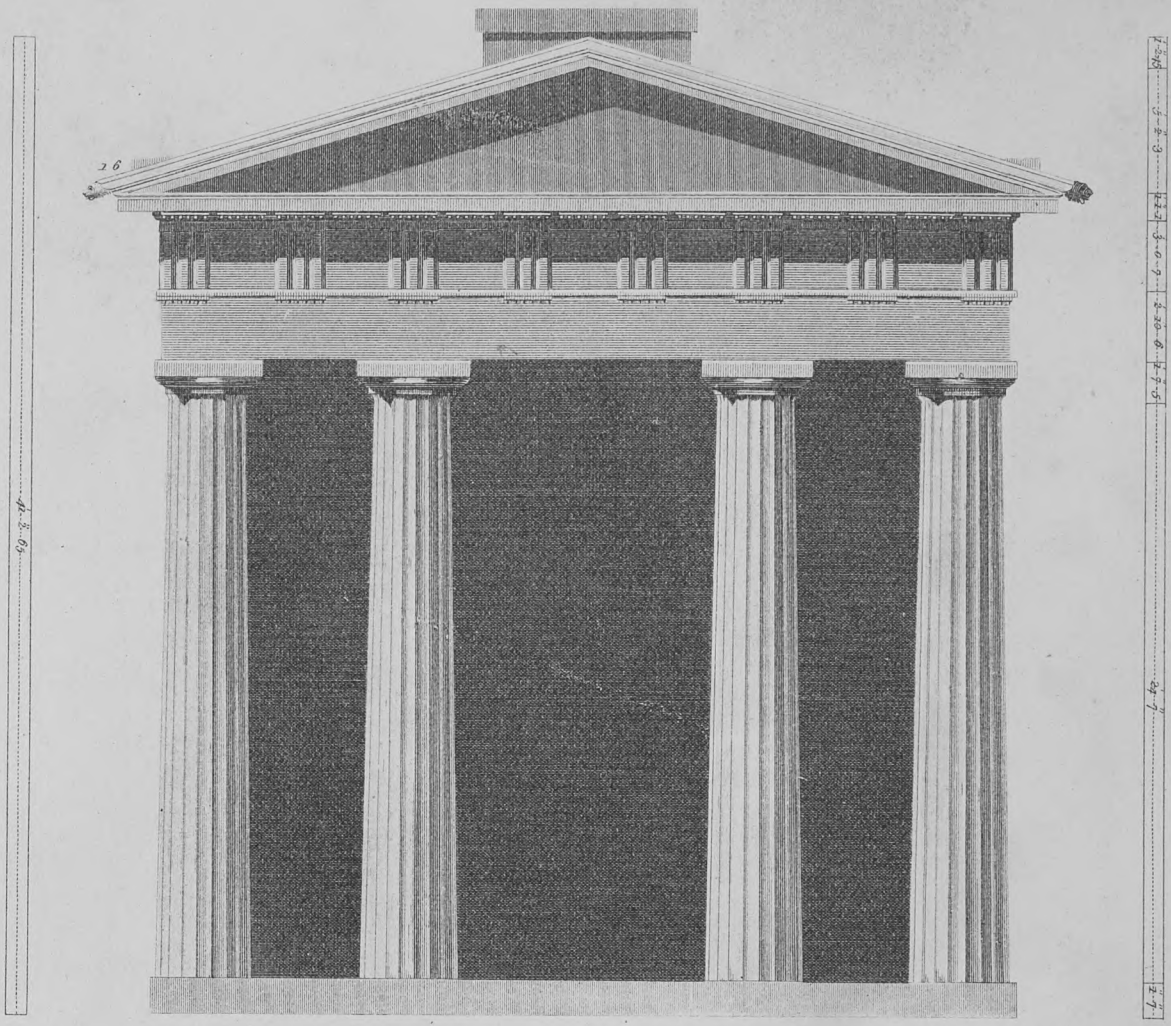
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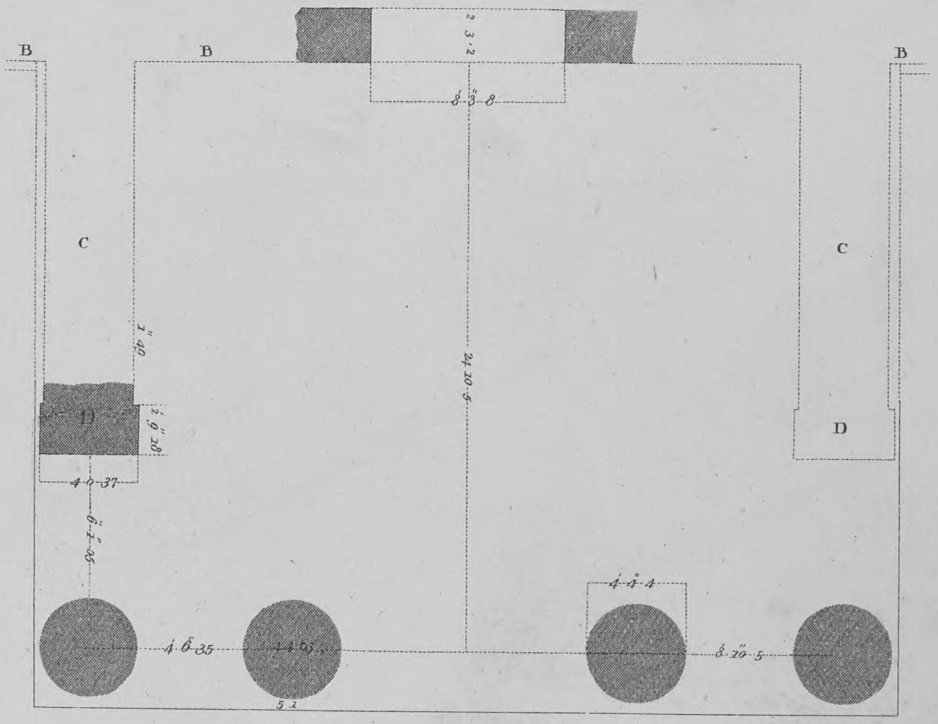


Drawn. by P. Nicholson.

Engd by R. Thew.

PORTICO.





PORTICO. PLATE. II.

The Ionic Temple on the Ilissus.



Engd by R. Thew.

Fig. 1.

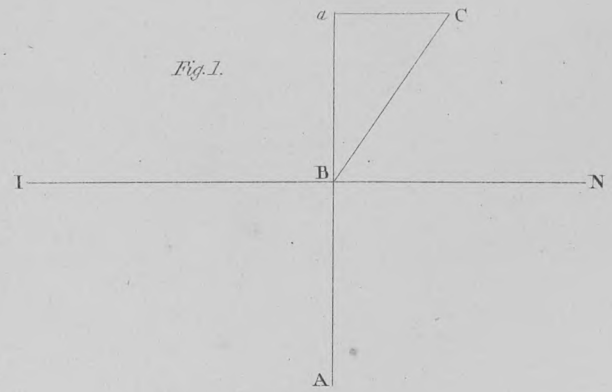


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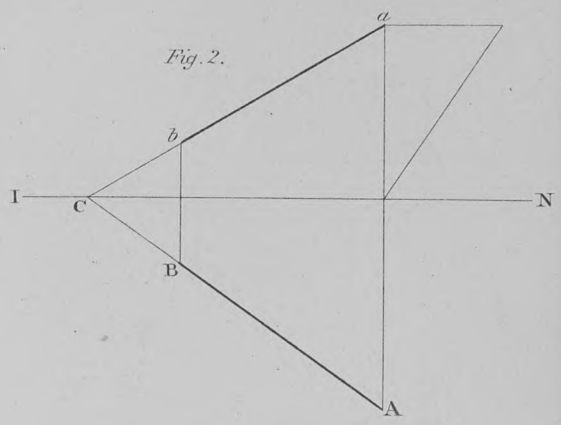


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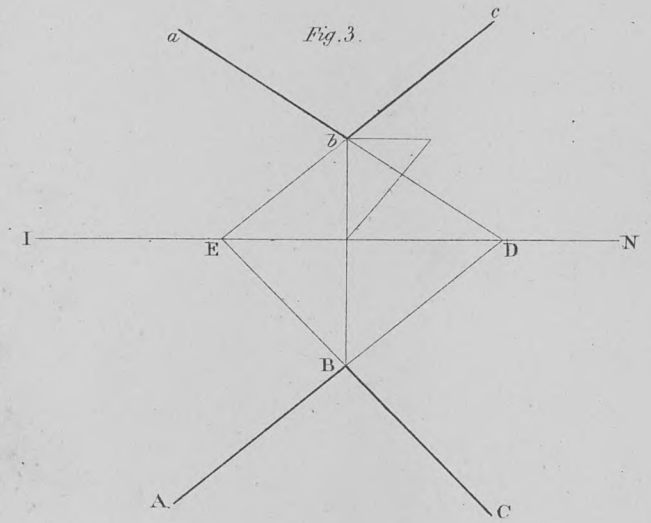


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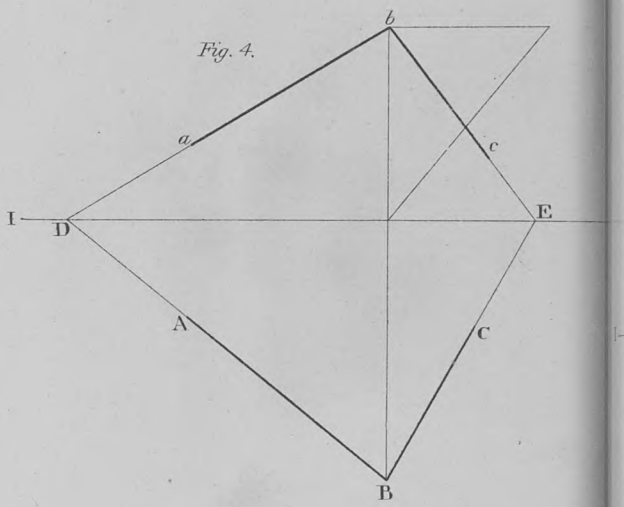


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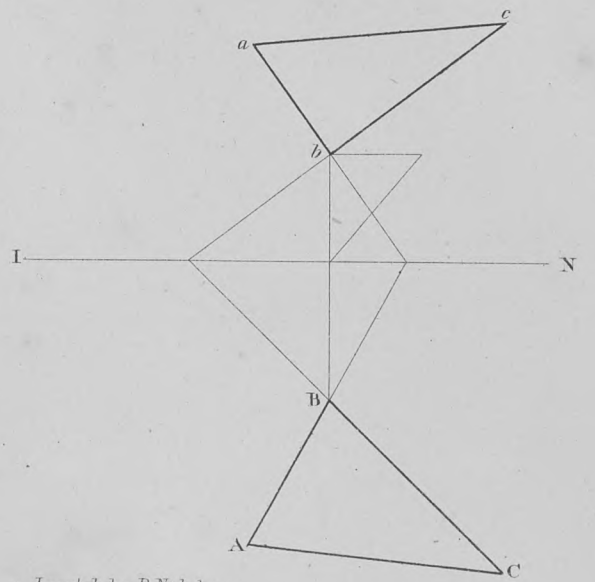
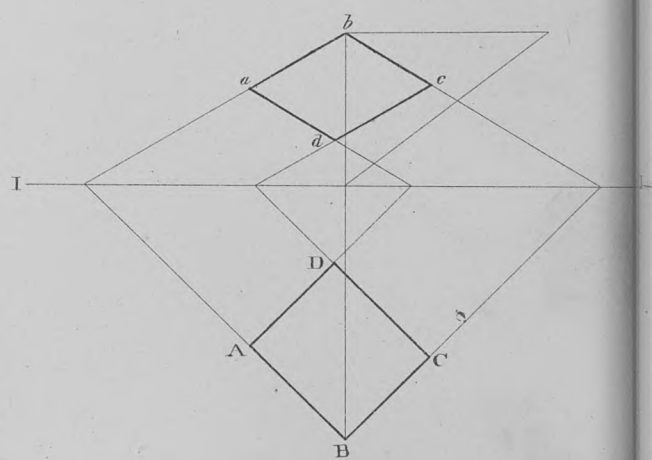


Fig. 6.



Invented by P. Nicholson.
Drawn by M.A. Nicholson.

Fig 1.

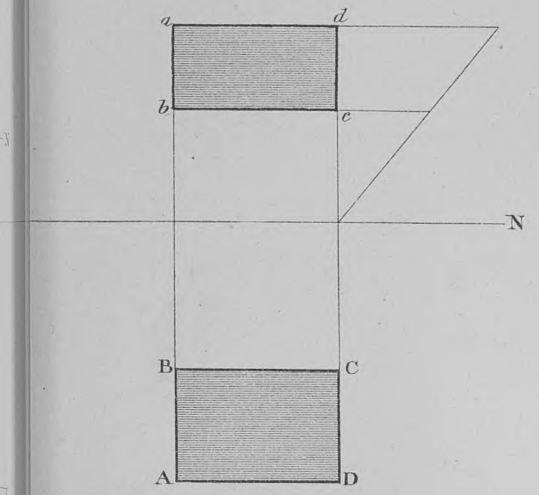


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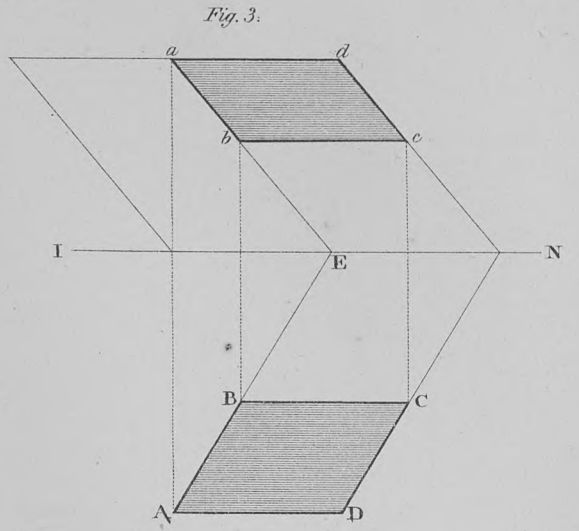


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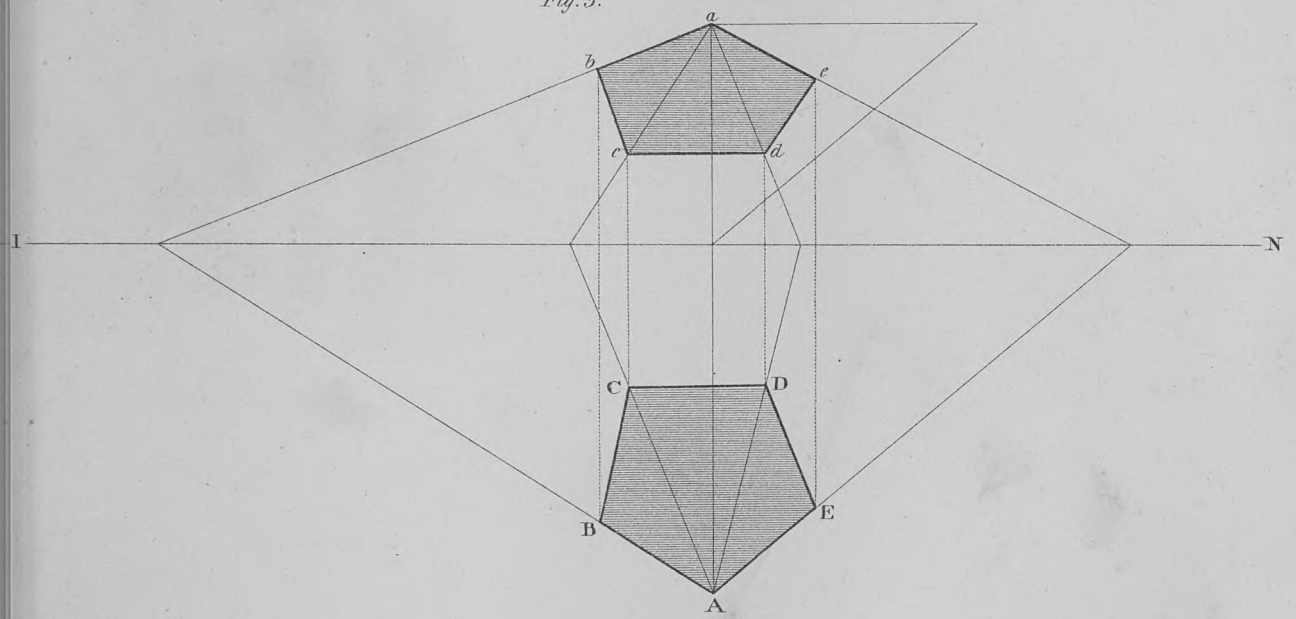
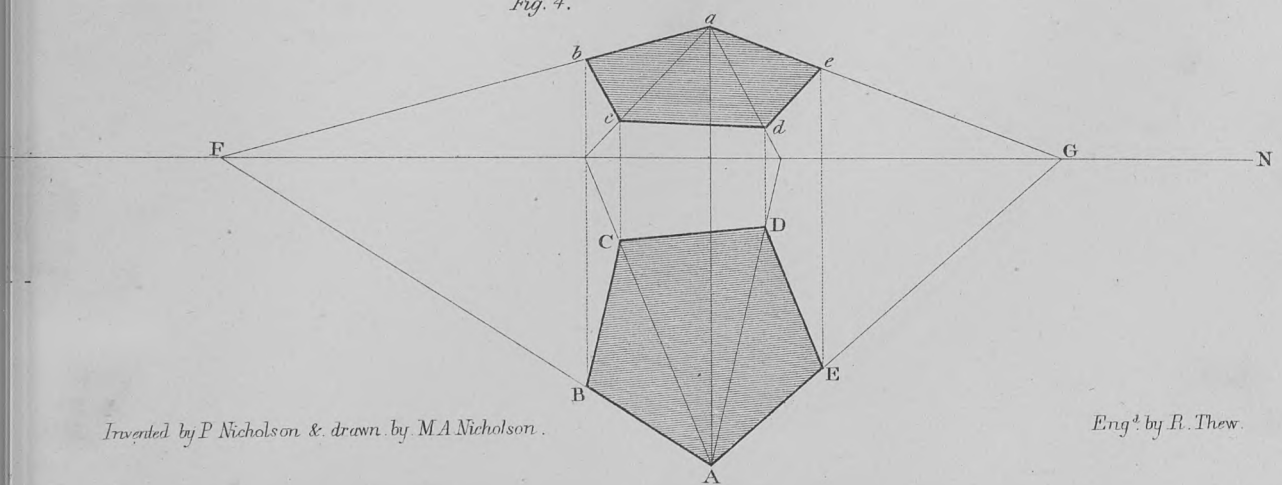


Fig. 4.



Invented by P Nicholson & drawn by M A Nicholson.

Engd. by R. Thew.

Fig. 1.

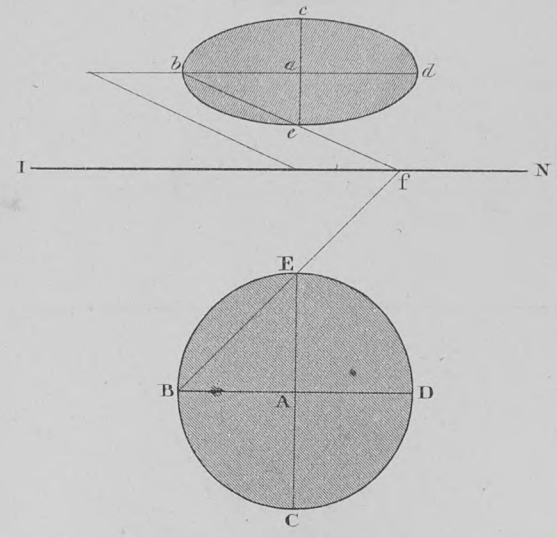


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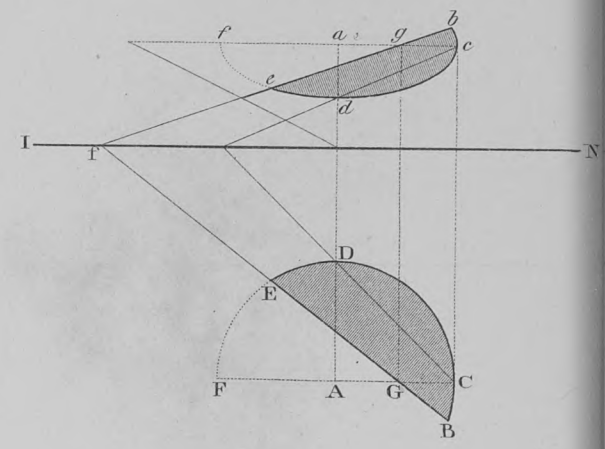


Fig. 3

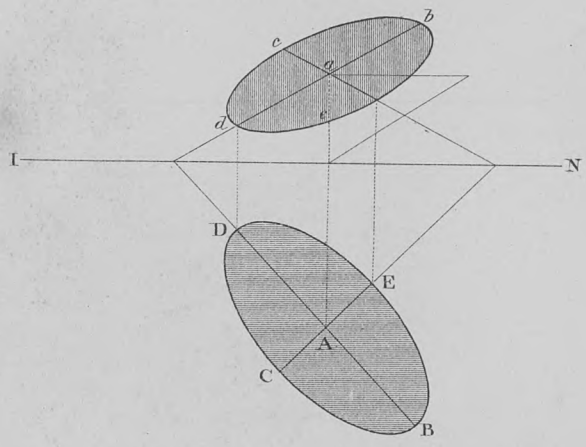


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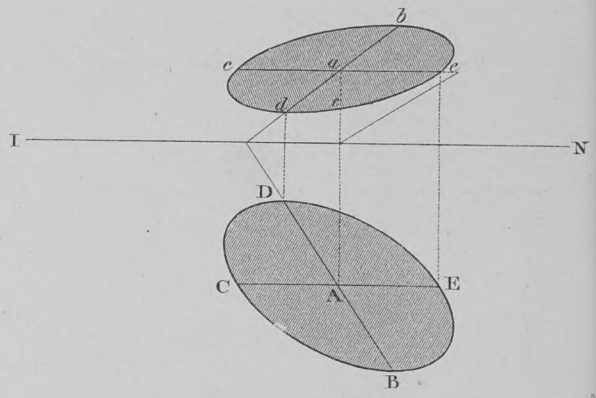


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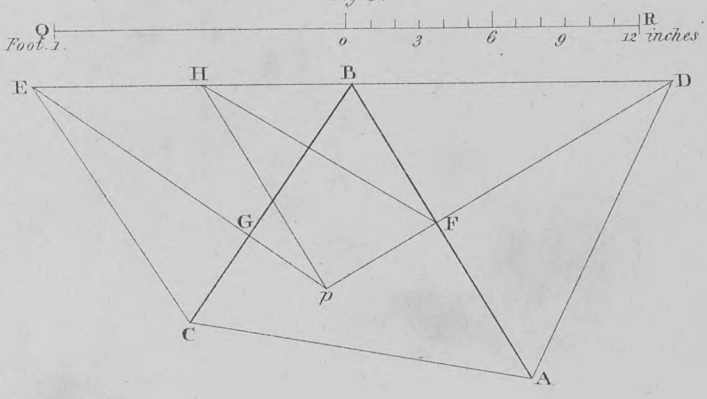
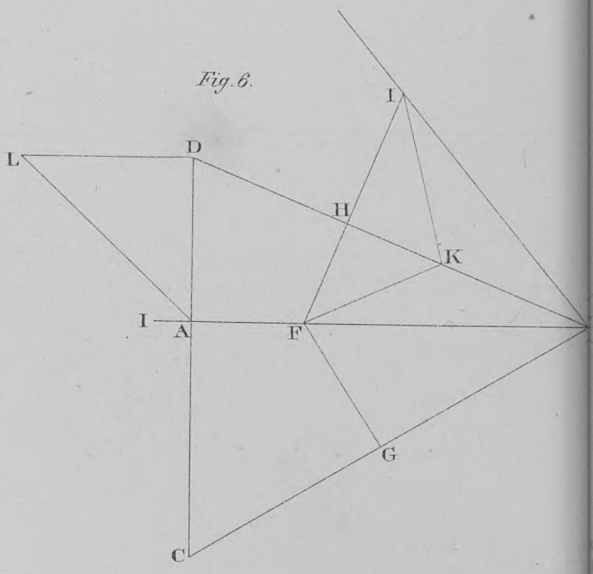


Fig. 6.



Invented by P. Nicholson &
Drawn by M.A Nicholson.

Engd by B. Thew.

Fig. 1.

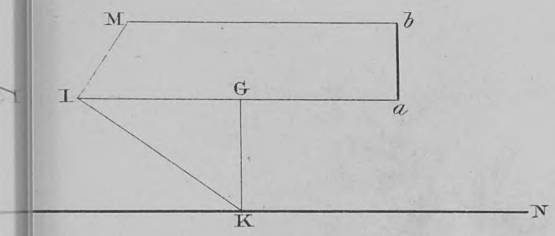


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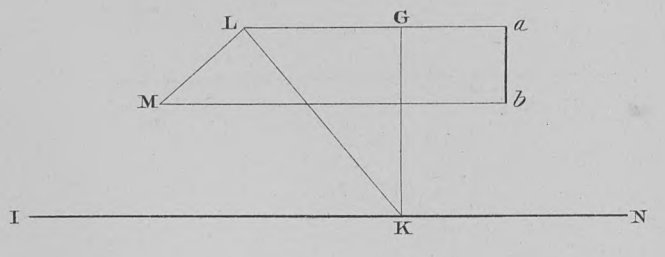


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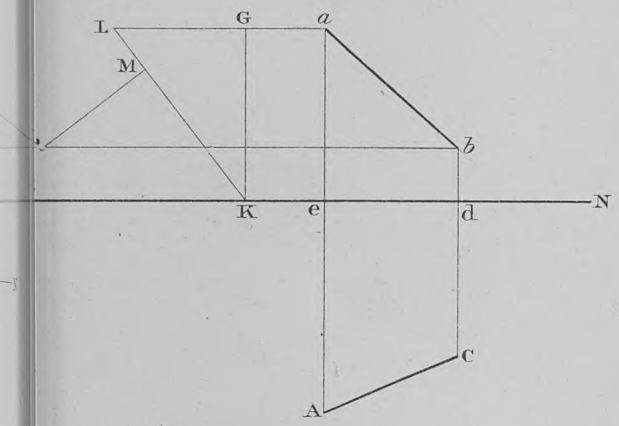


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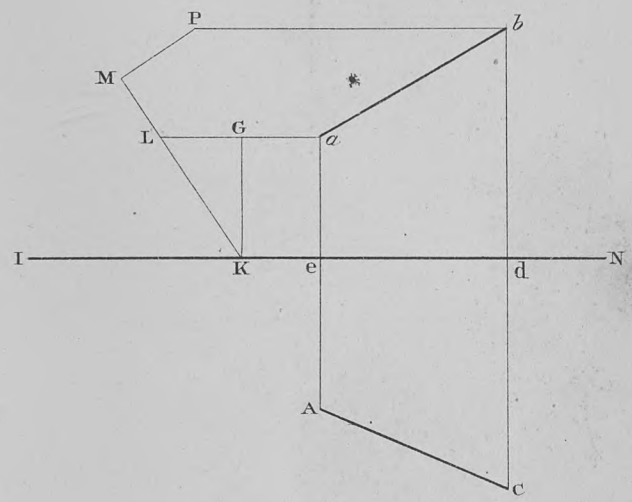
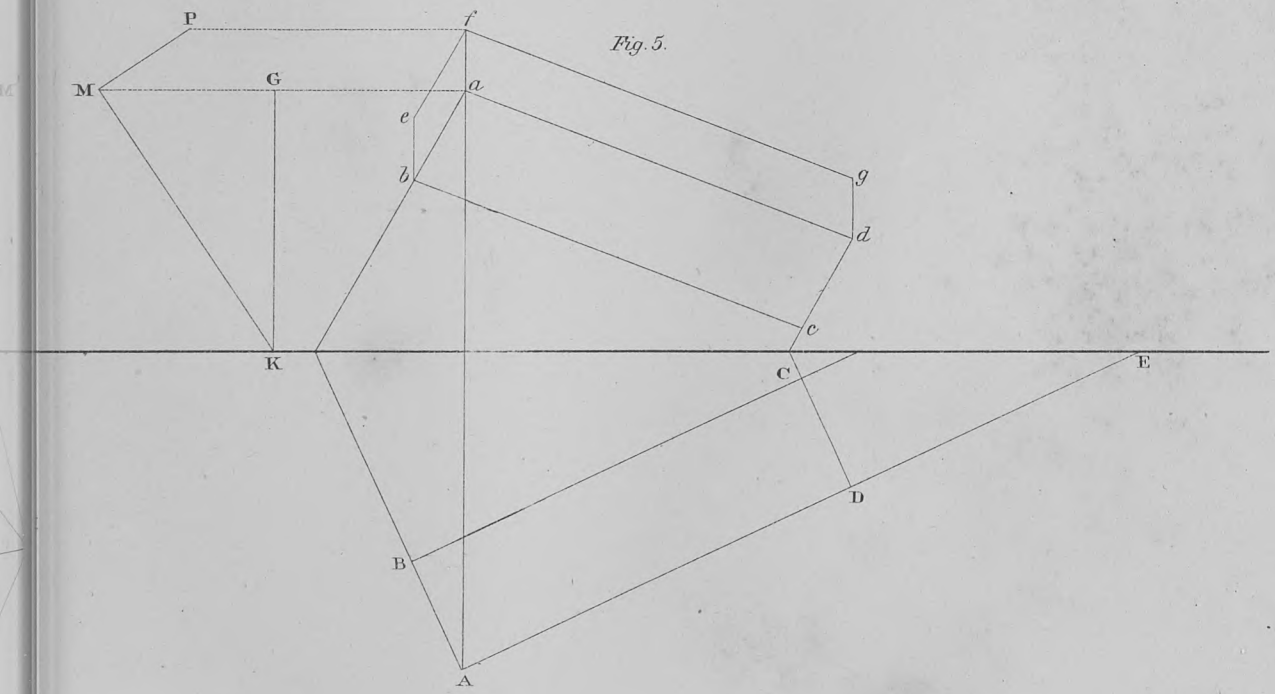


Fig. 5.



by P. Nicholson, and M. A. Nicholson.

Eng^d by R. Thew.

Fig. 1.

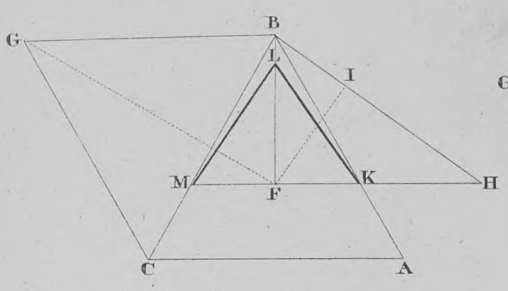


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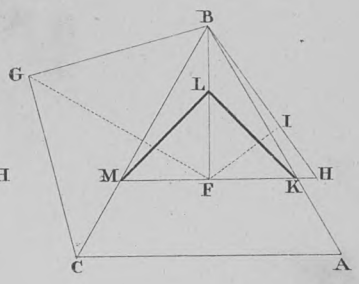


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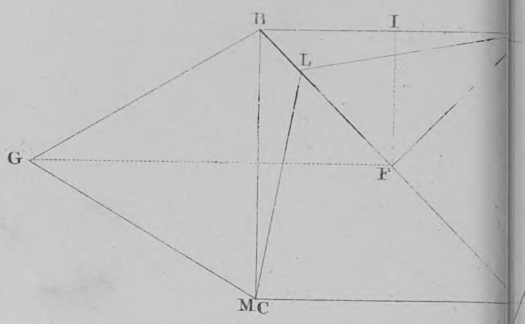


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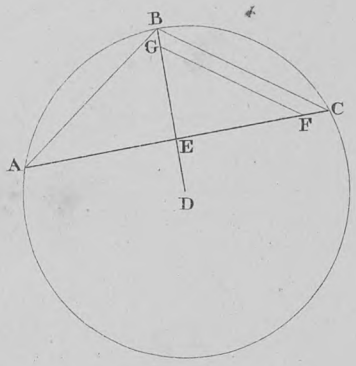


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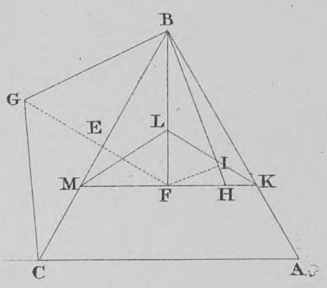


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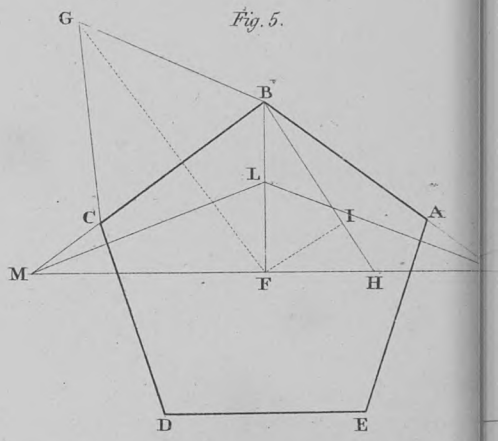


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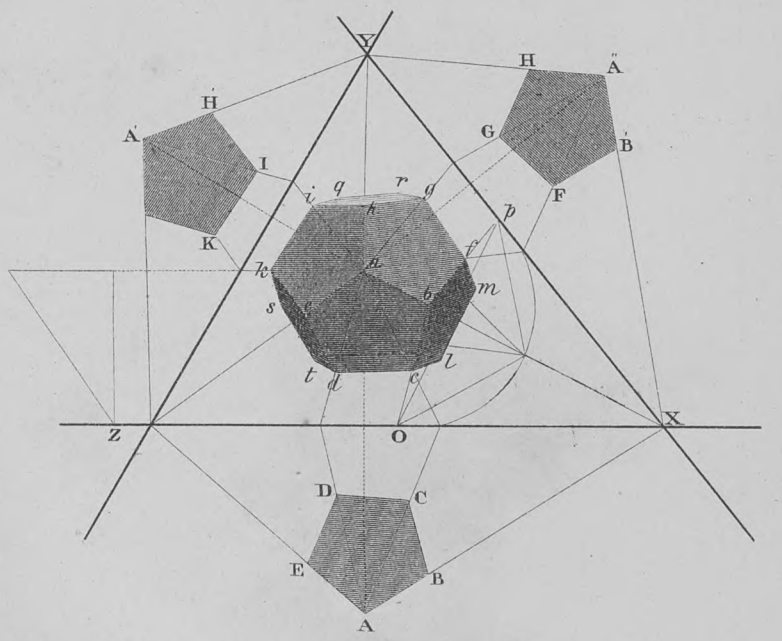
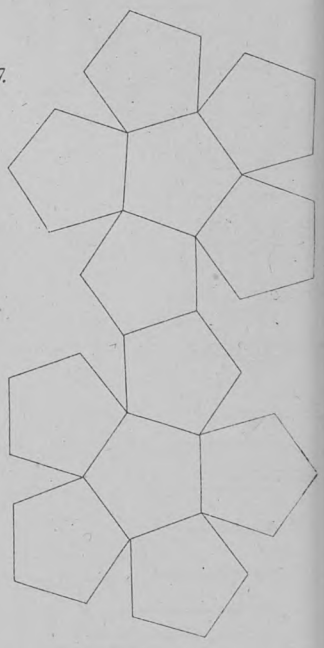


Fig. 7.



Invented & Drawn by P. Nicholson.

Engd by R. Thew.

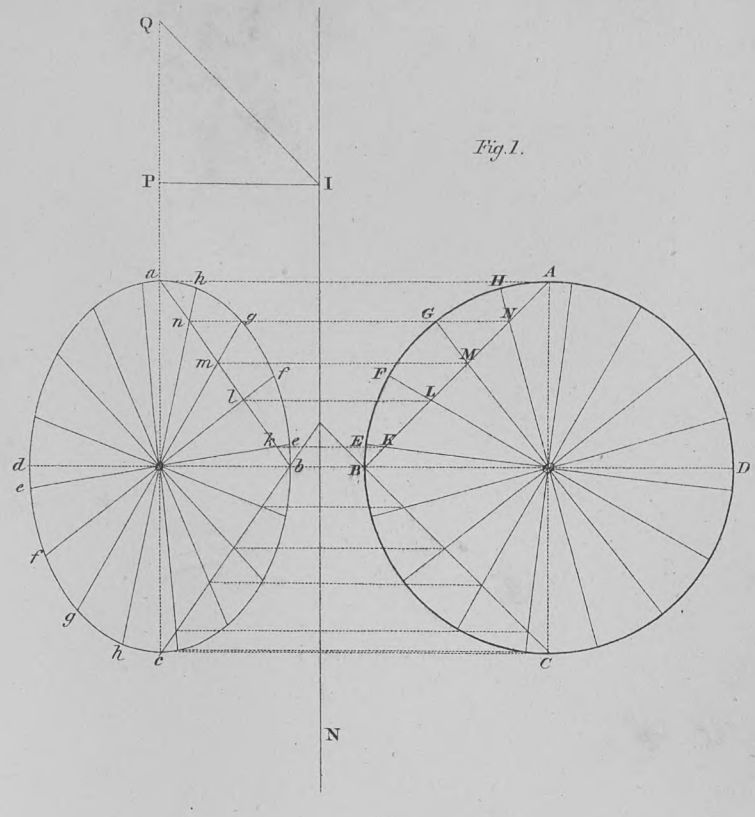
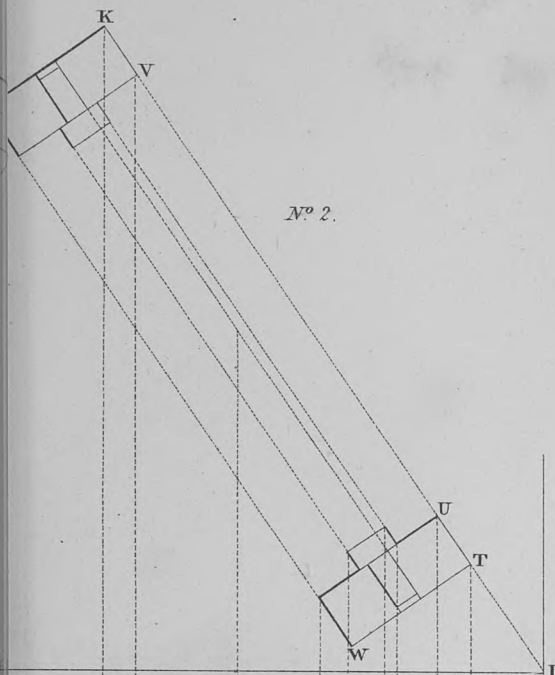
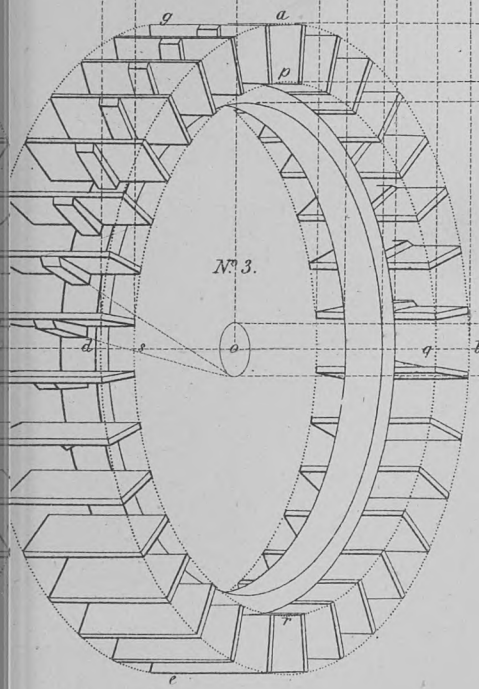


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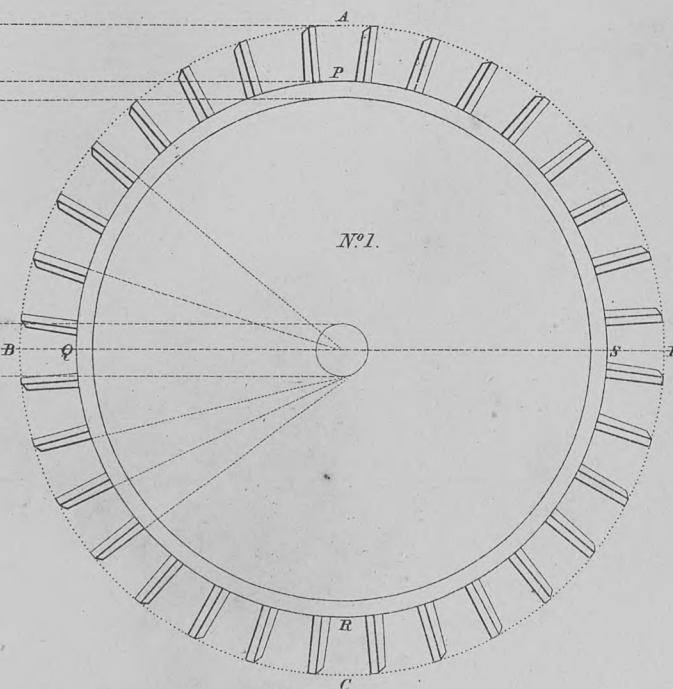


N.º 2.

Fig. 2.



N.º 3.



N.º 1.

N
I

Fig. 3.

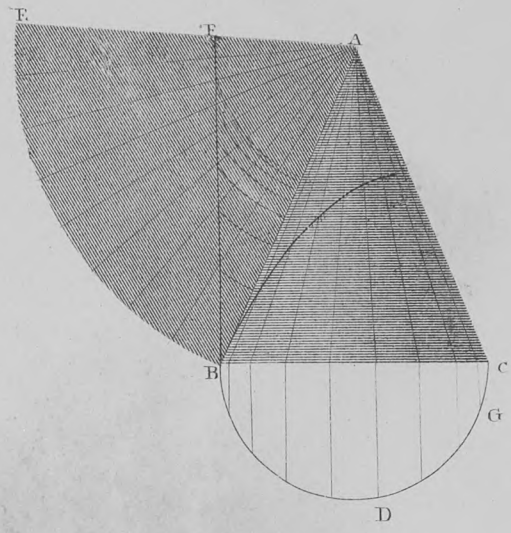


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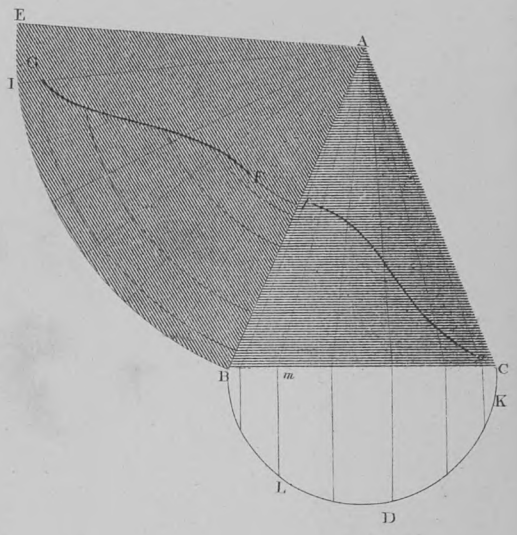


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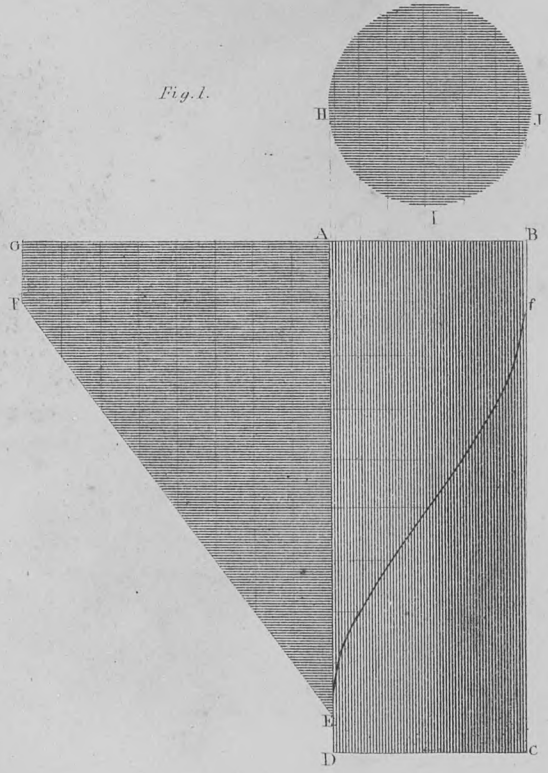
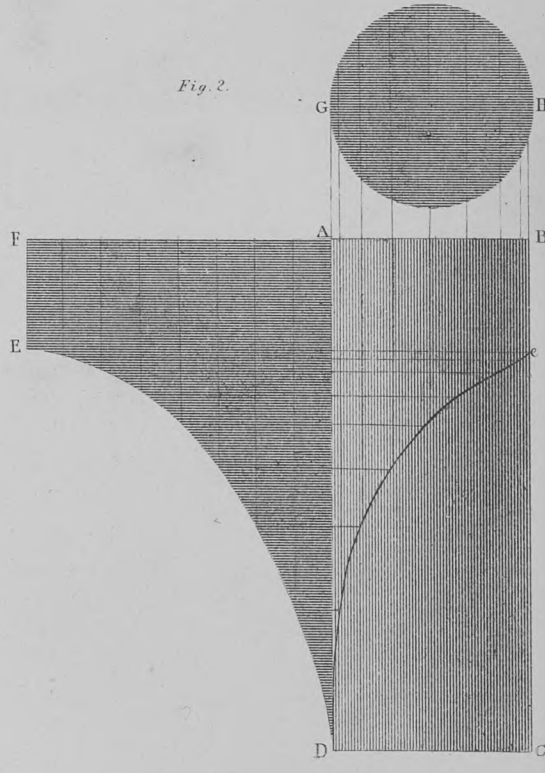


Fig. 2.



Drawn by P. Nicholson.

Engraved by

PROJECTION.

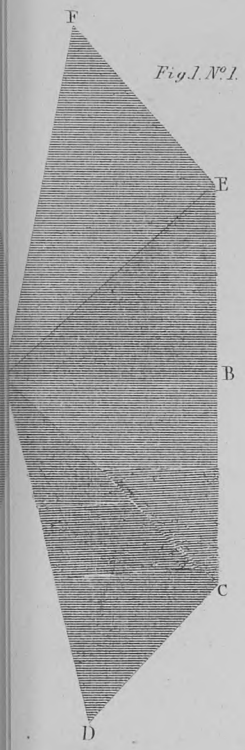


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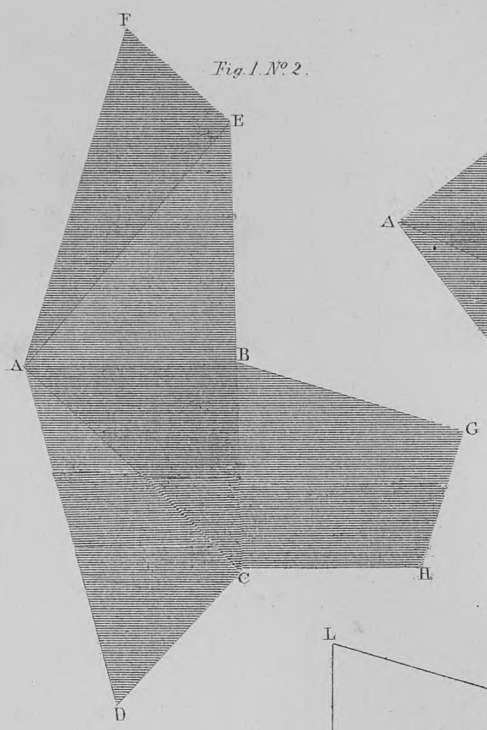


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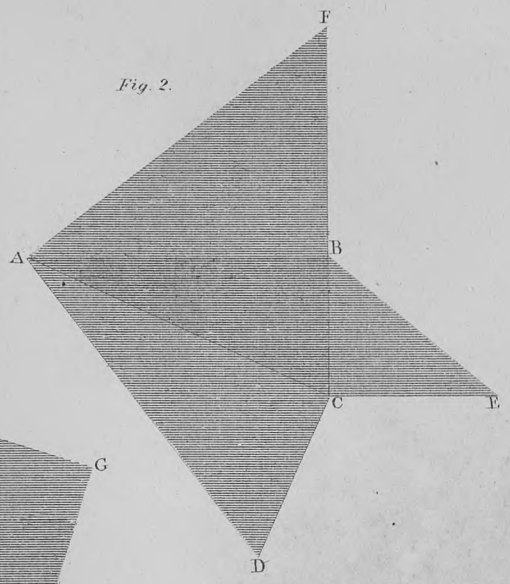


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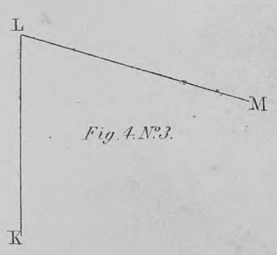


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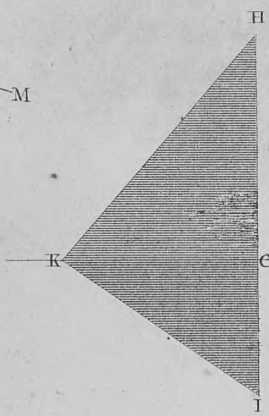


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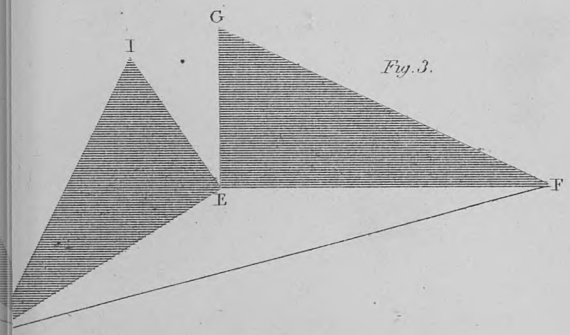


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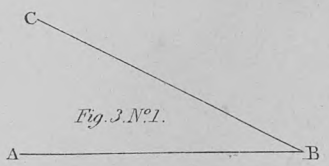


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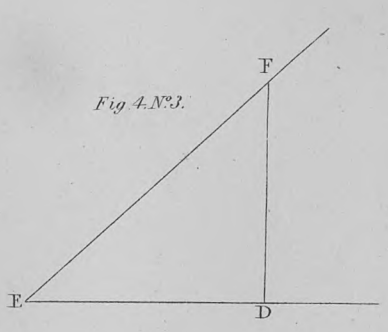


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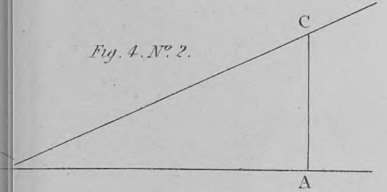


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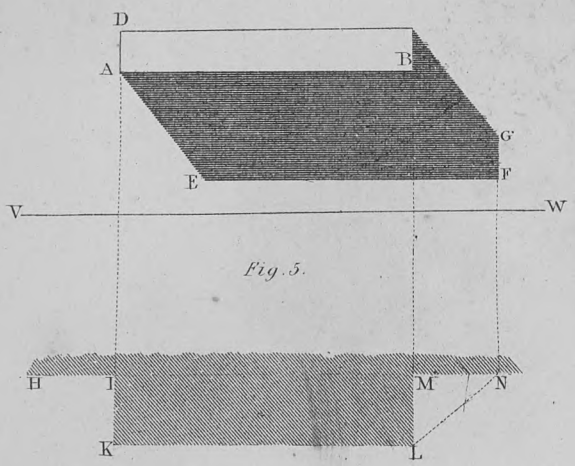


Fig. 5.

Nicholson.

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PROJECTION.

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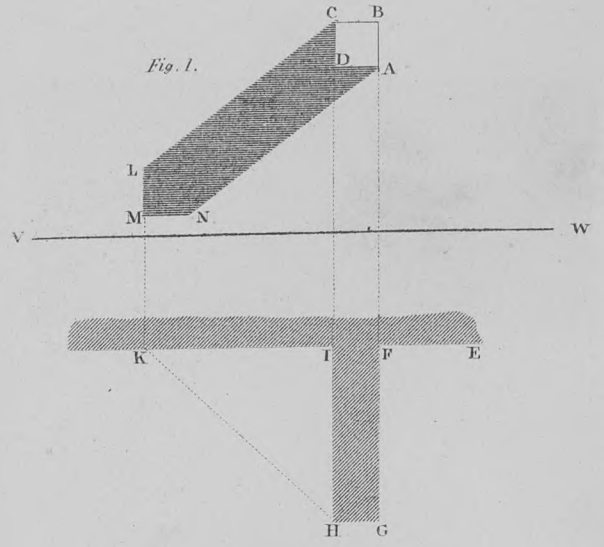
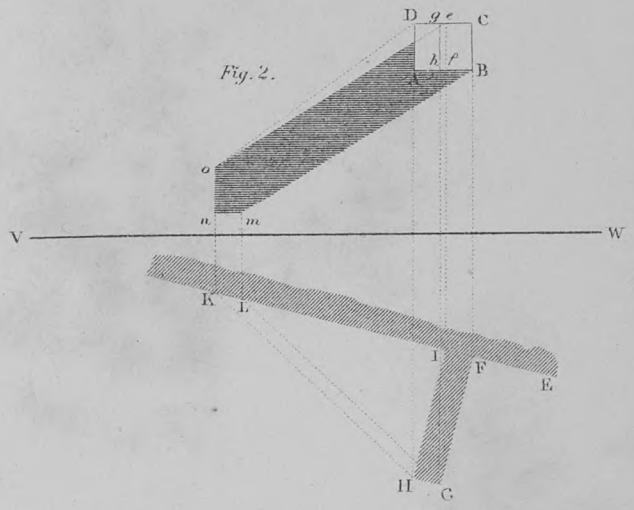


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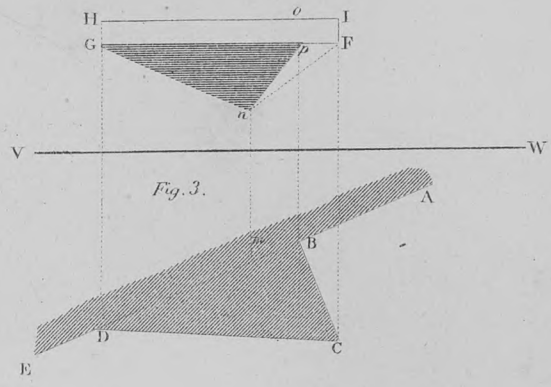


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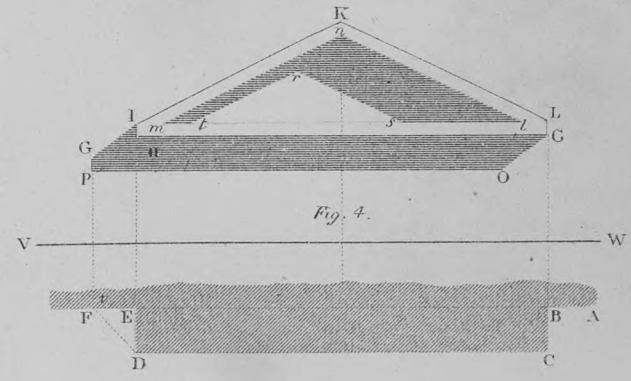


Fig. 4.

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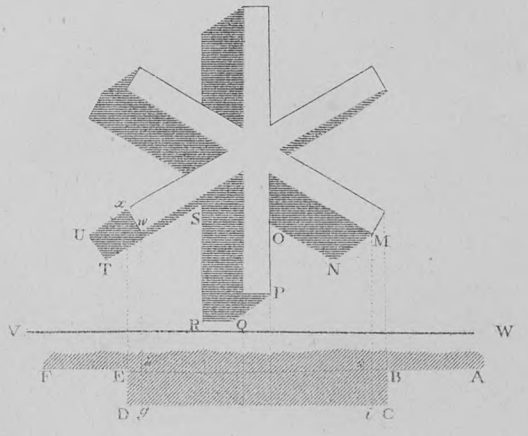
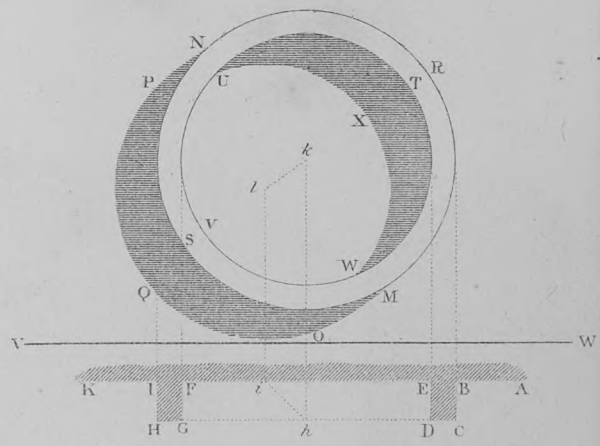


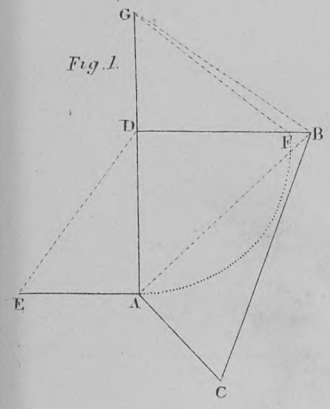
Fig. 6.



Invented & Drawn by P. Nicholson

Engraved by J.C.Buth

Fig. 1.



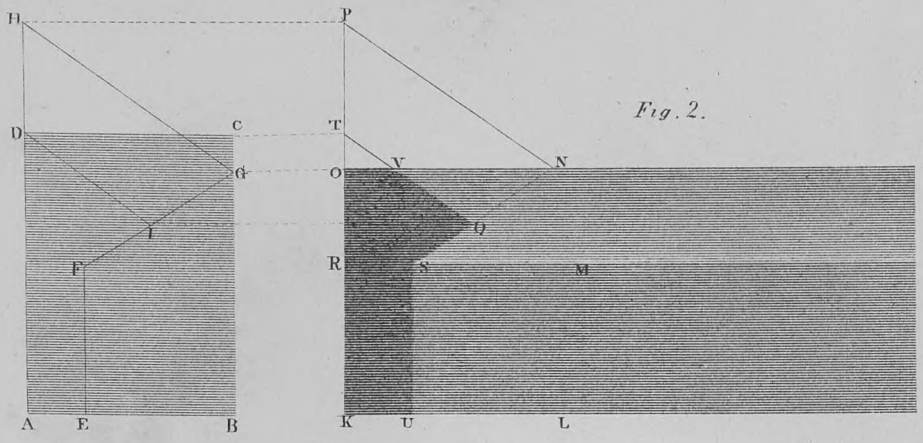


Fig. 2.

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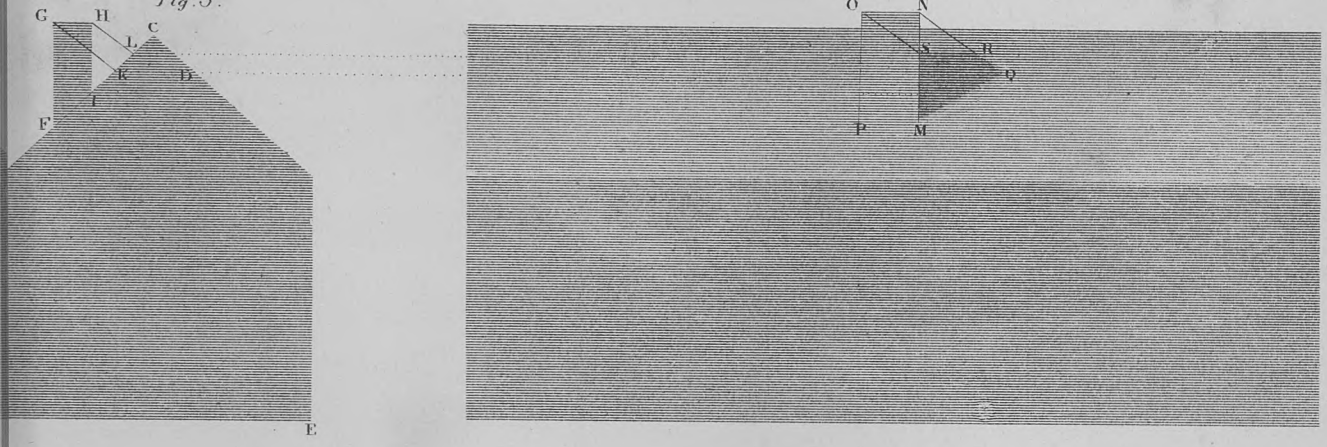


Fig. 3.

Fig. 4.

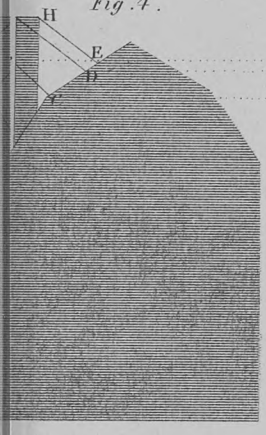
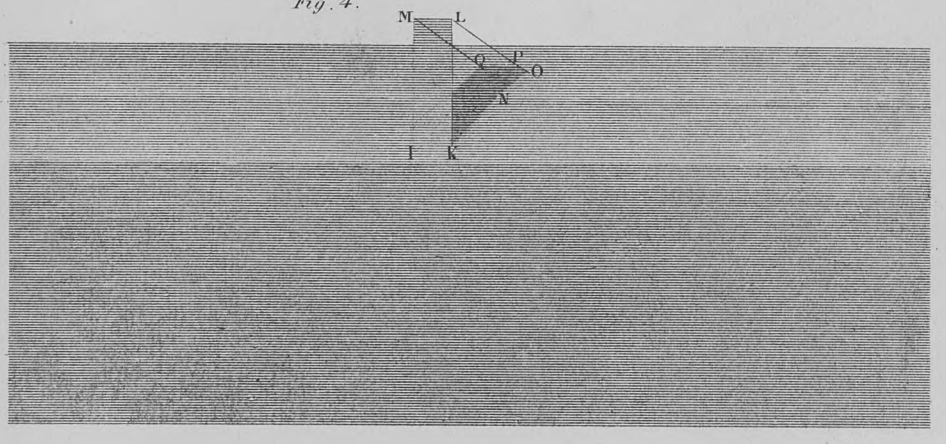


Fig. 4.



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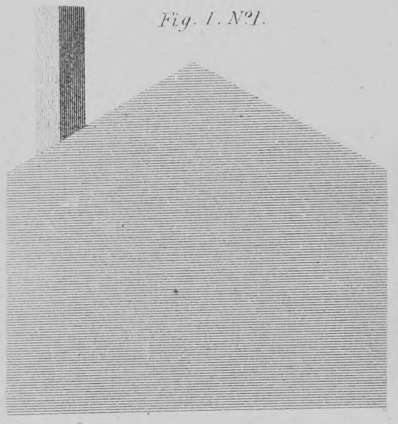


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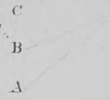


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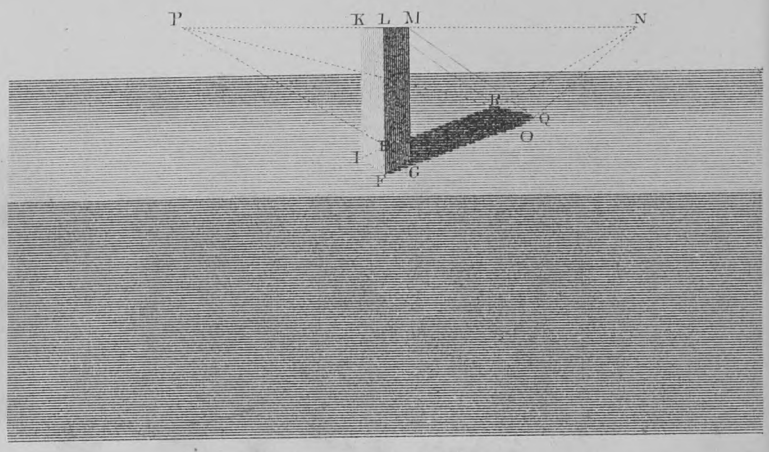


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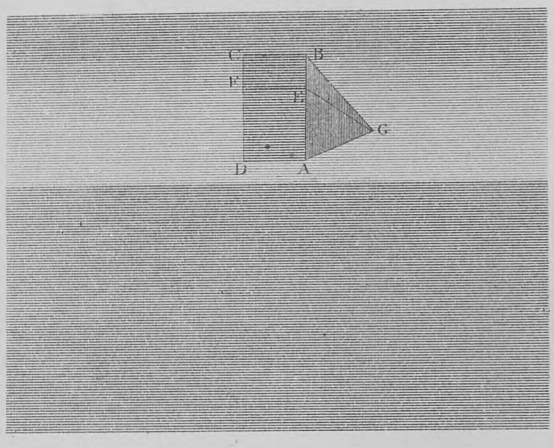


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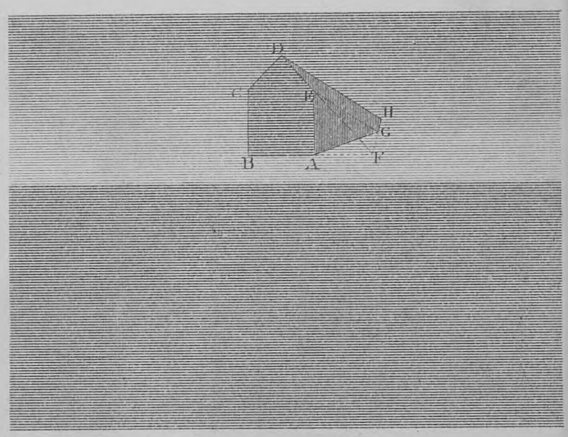


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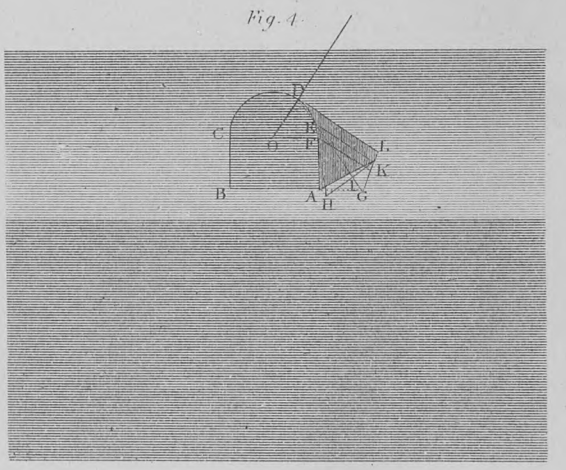
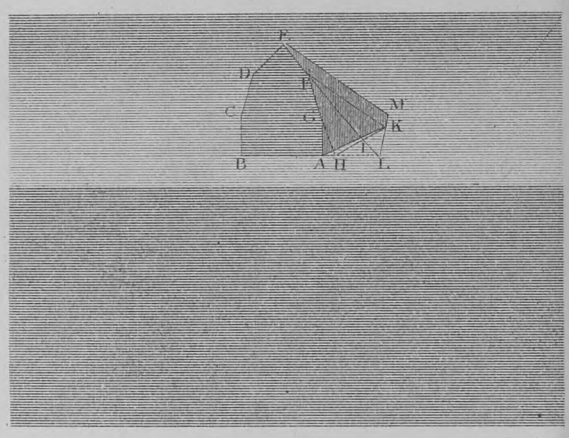


Fig. 5.



Drawn by P. Nicholson.

Engraved by J.C.L

PROJECTION.

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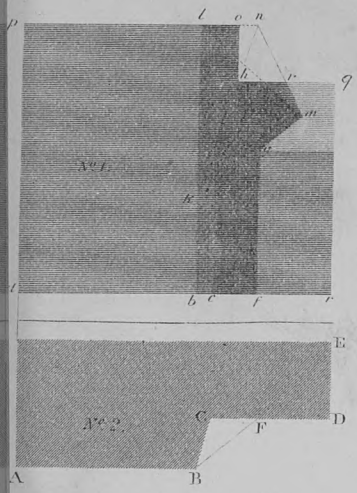


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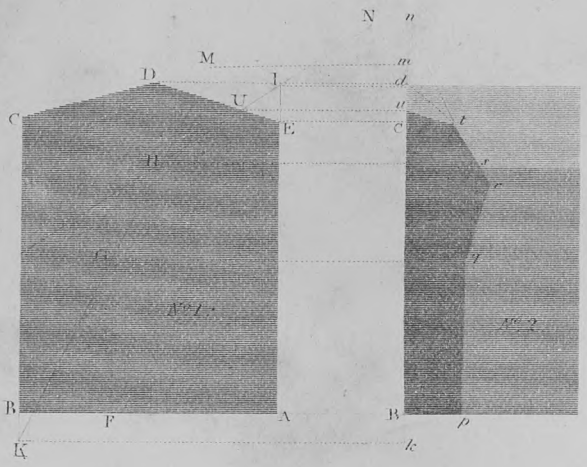


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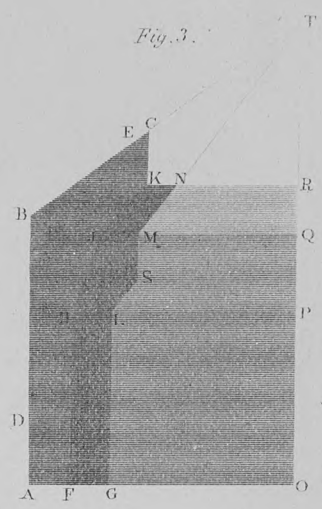


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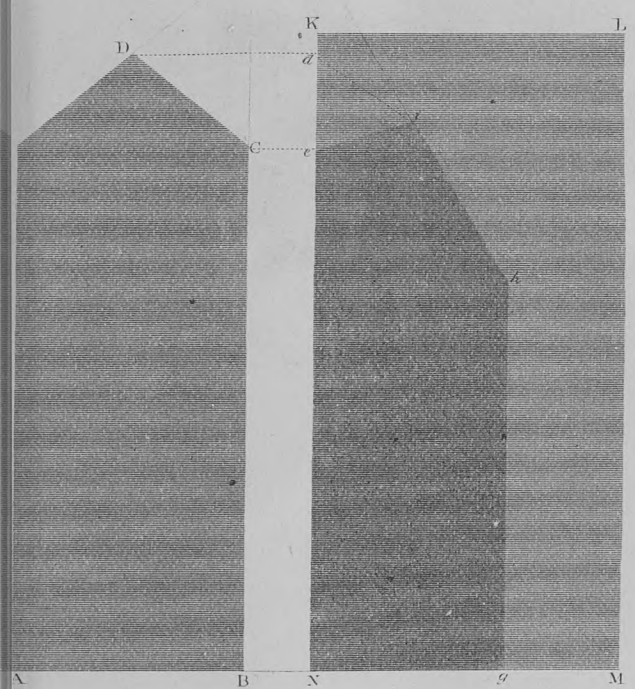
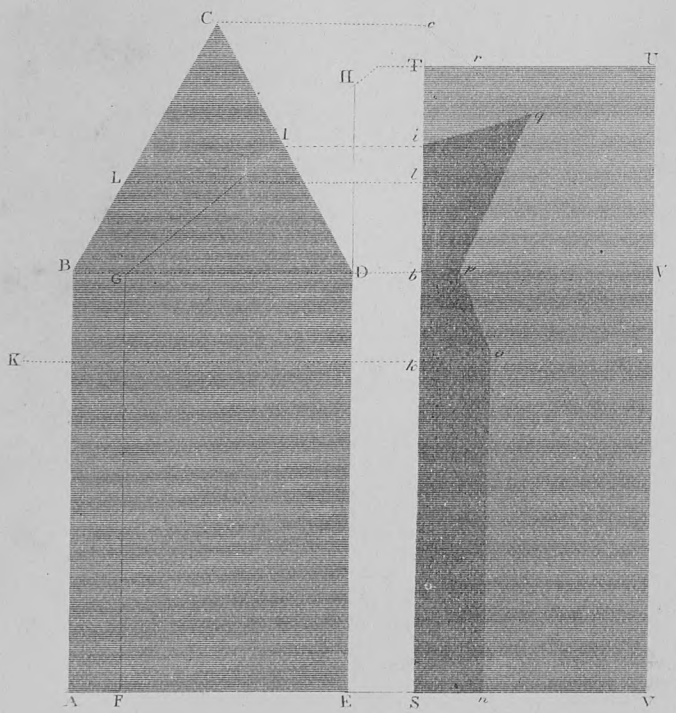


Fig. 5



by P. Nicholson.

Engraved by J.C.Buttre.

Fig 1 N°1

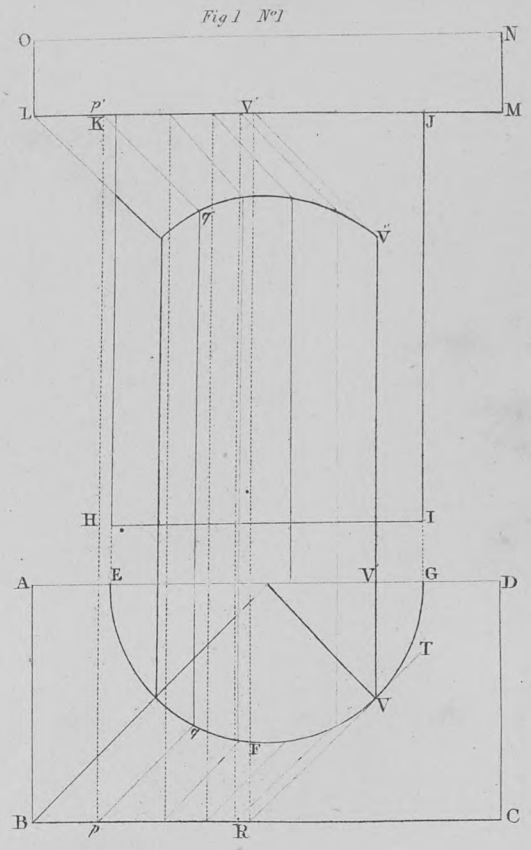


Fig 1 N° 2

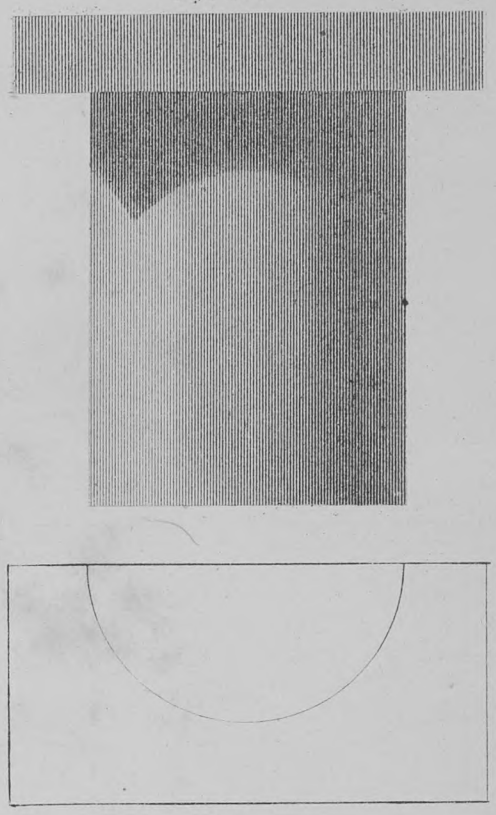


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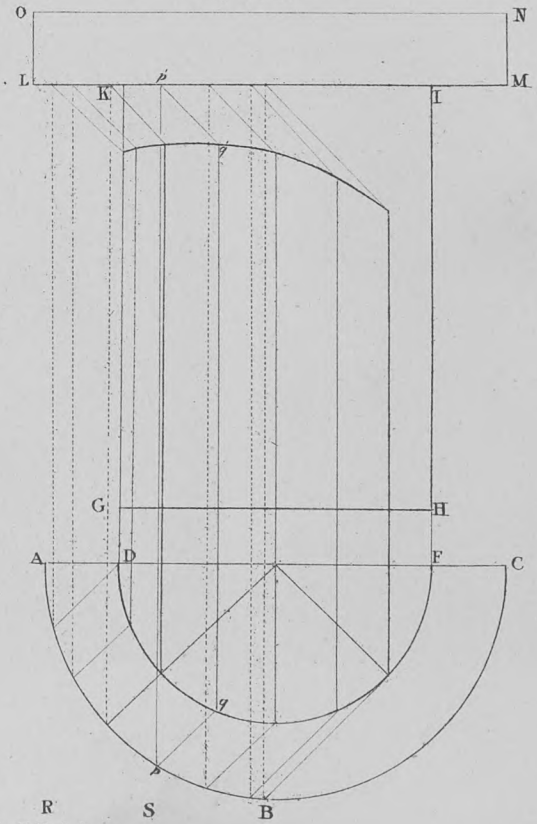
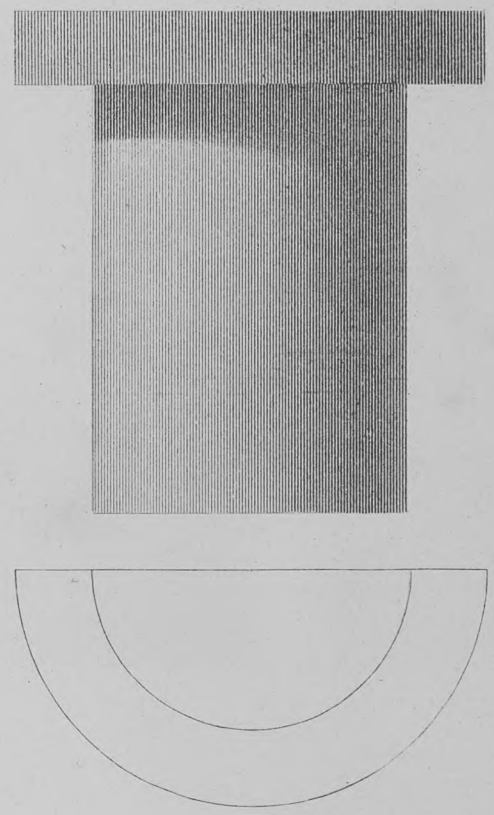


Fig 2. N° 2.



Drawn by P Nicholson

Engraved by J.C.Buttre

PROPORTIONAL COMPASSES.

PLATE. I.

Fig. 1.

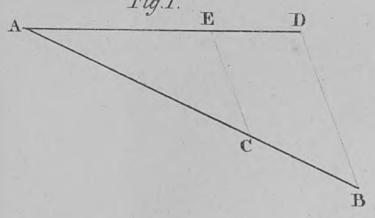


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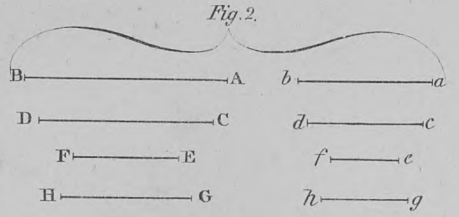


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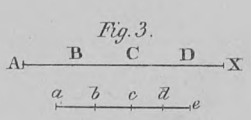


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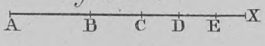


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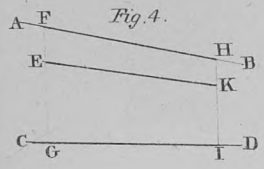


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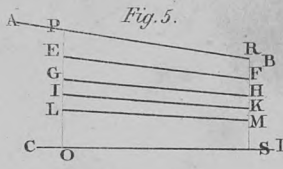


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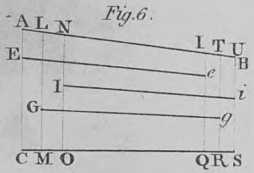


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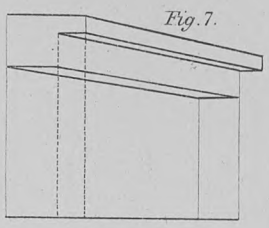


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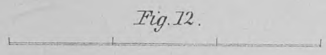


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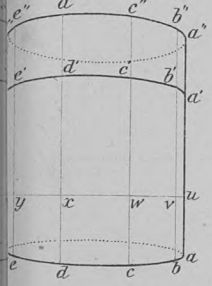
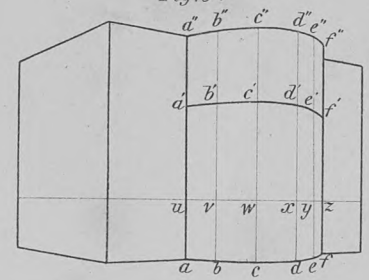


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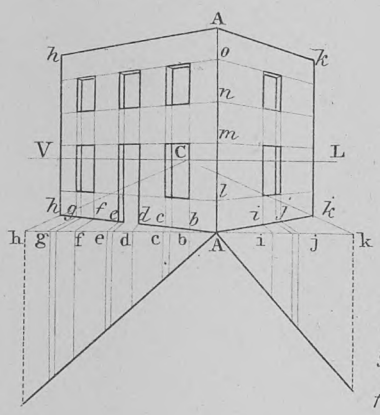


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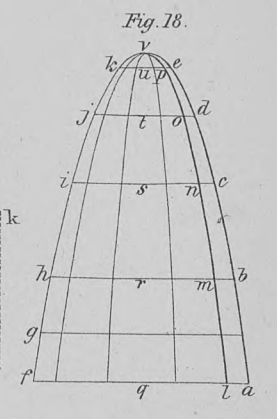


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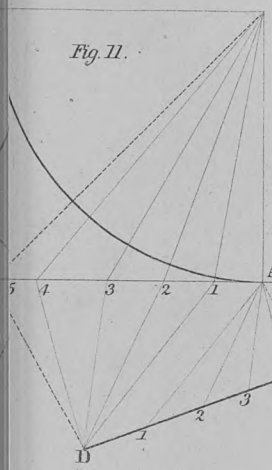


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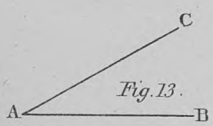
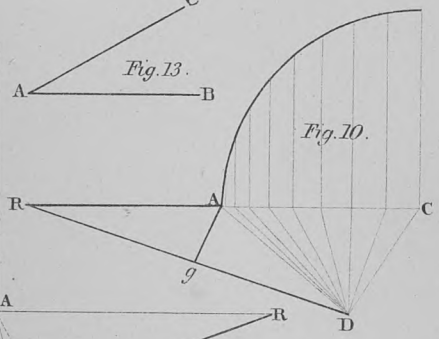


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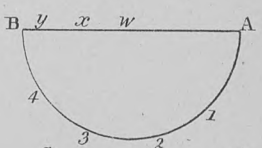


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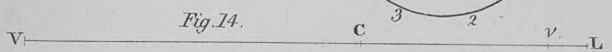


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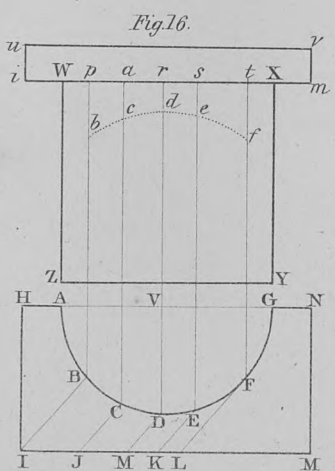


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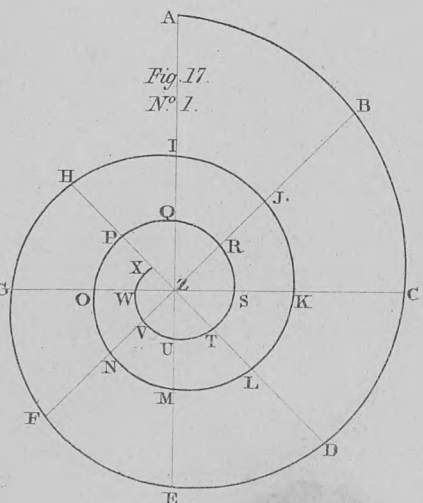


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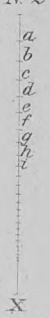


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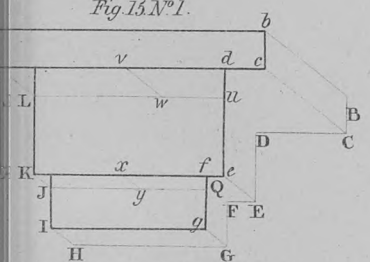
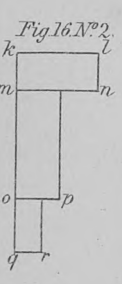


Fig. 16. N° 2.



Drawn by P. Nicholson.

Fig. 3.

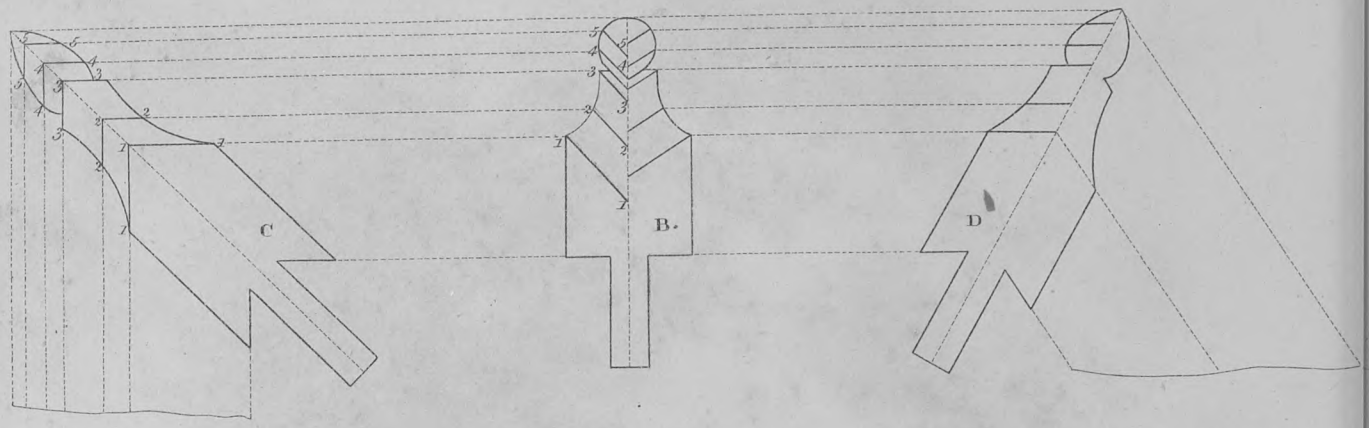


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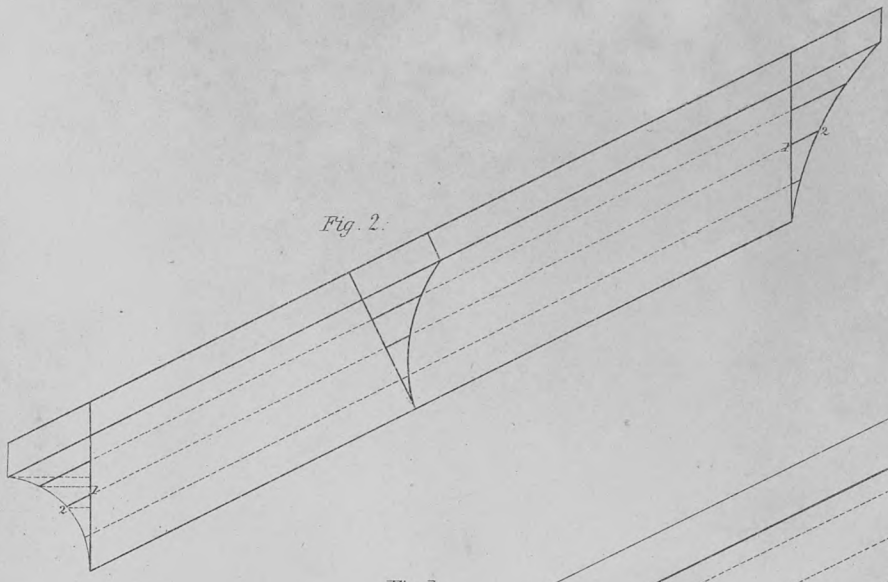
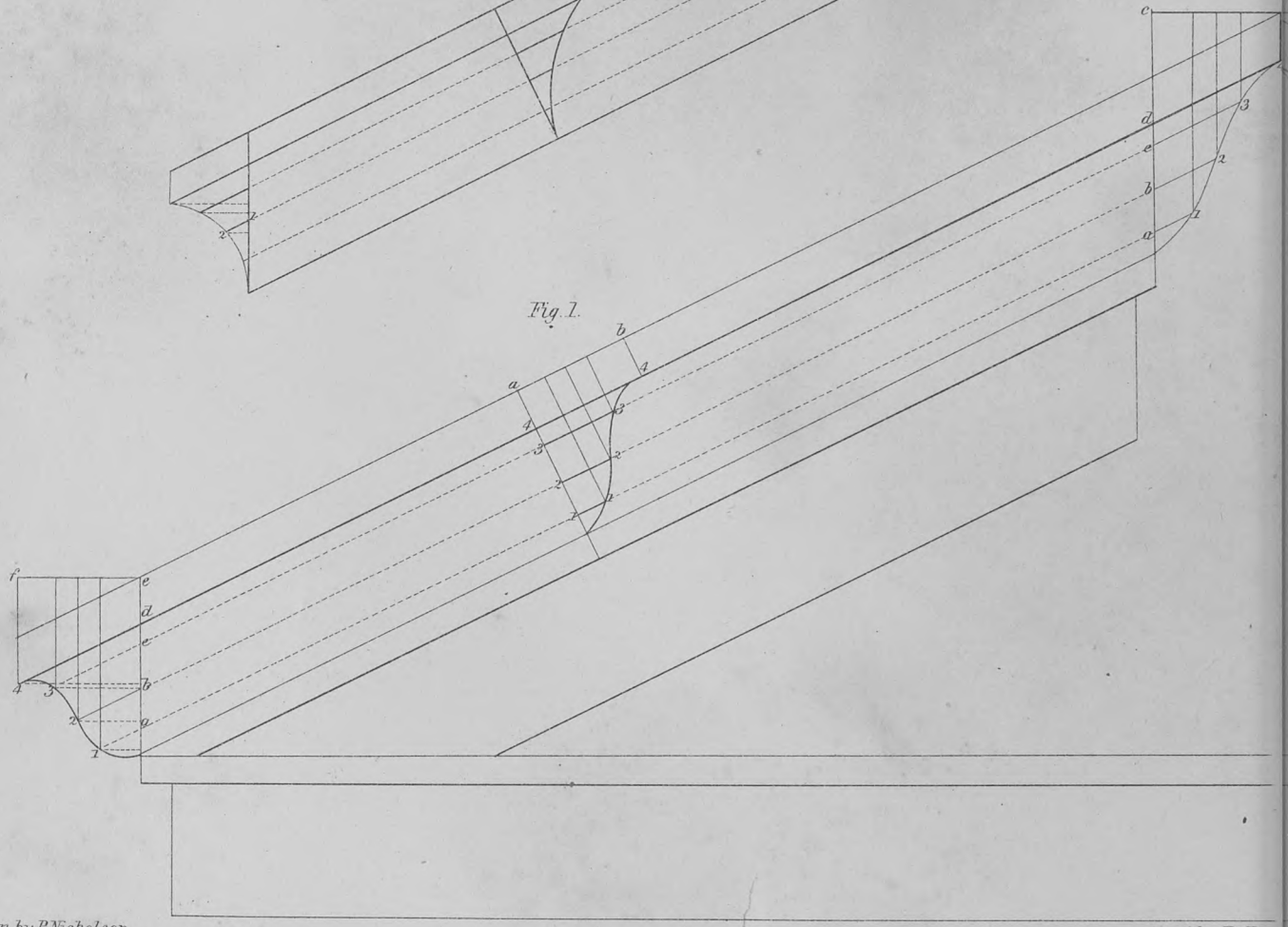
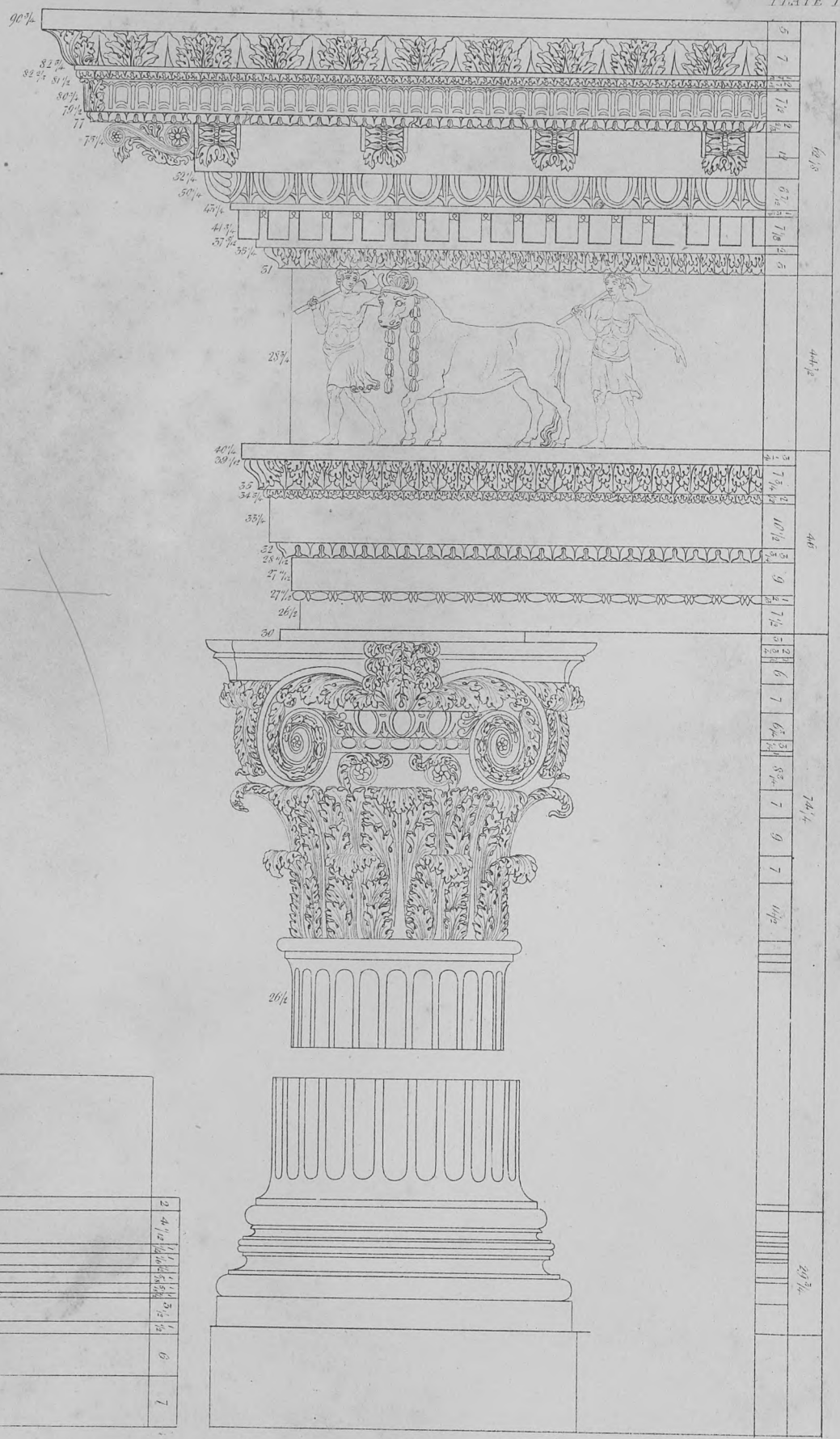


Fig. 1.



Drawn by P Nicholson.

Engd by R. Thew


90 3/4
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82 3/4
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80 3/4
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77
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P. Nicholson.
H. Thew sc.

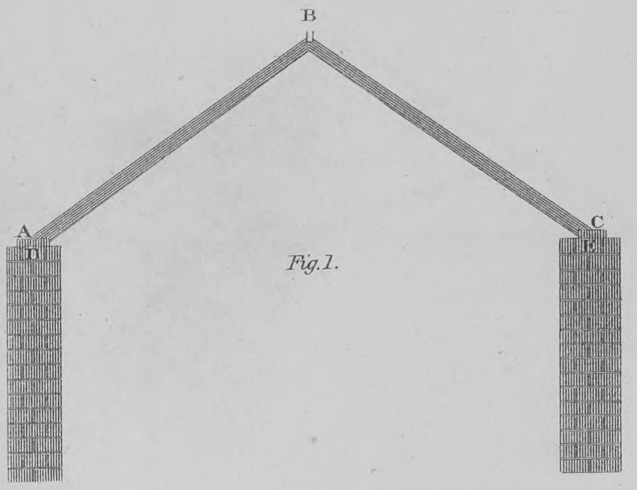


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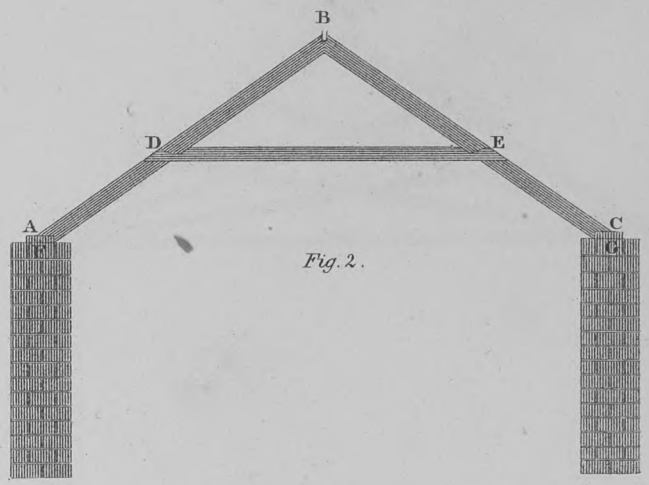


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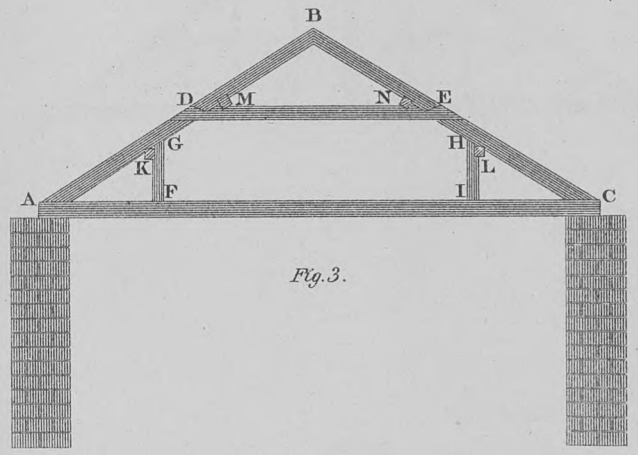


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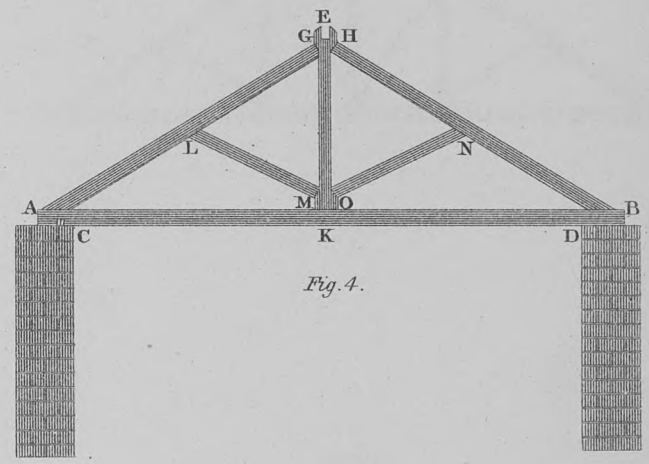


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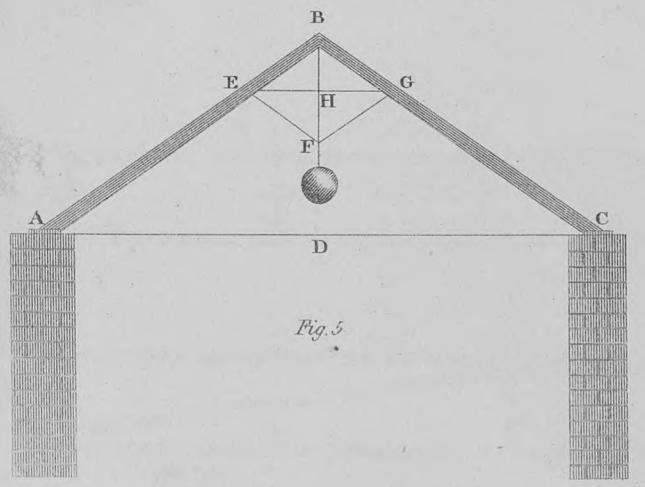


Fig. 5

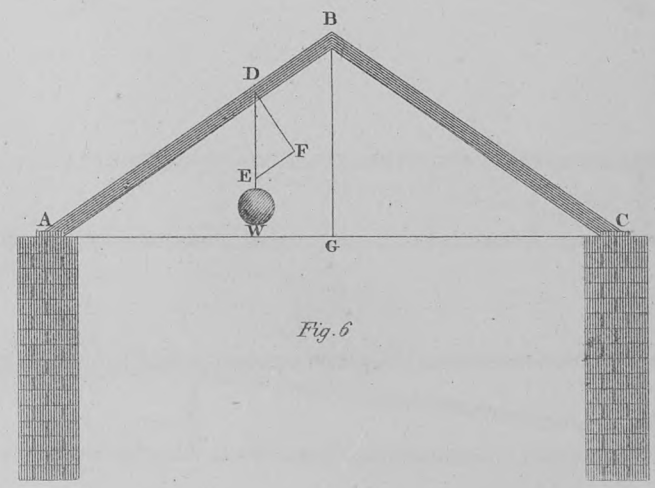


Fig. 6

Drawn. by M A Nicholson *Eng[d] by R. Thew*

ROOF.

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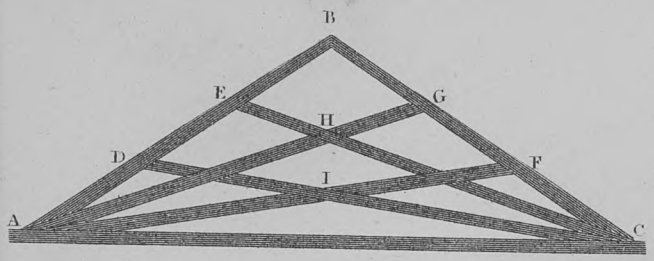


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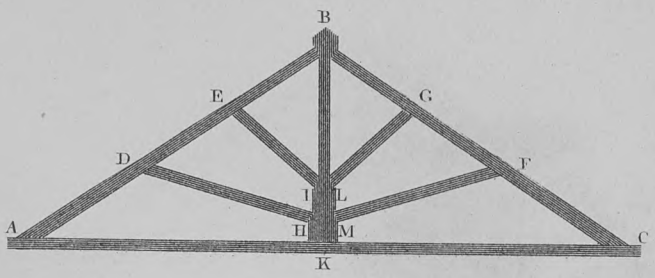


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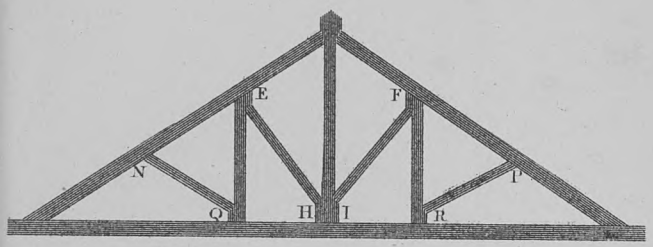


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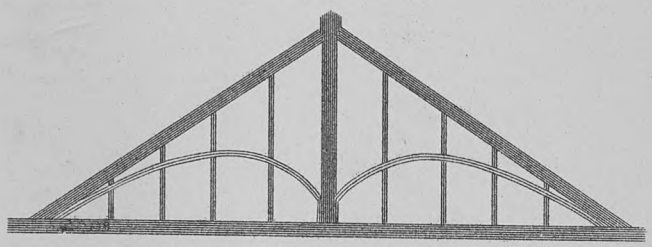


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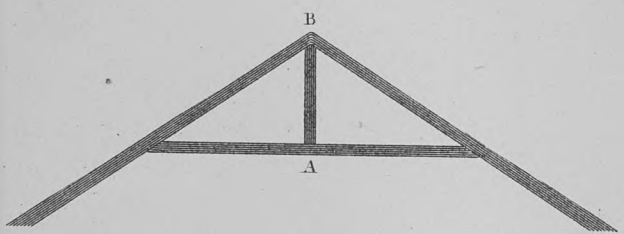


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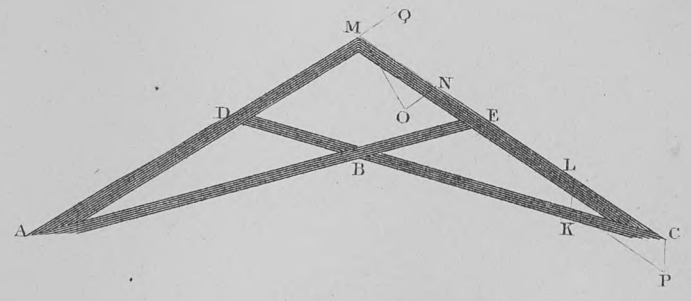


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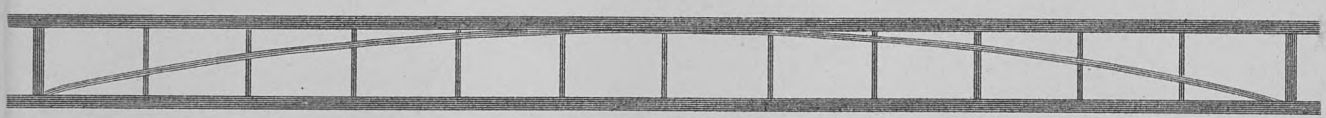
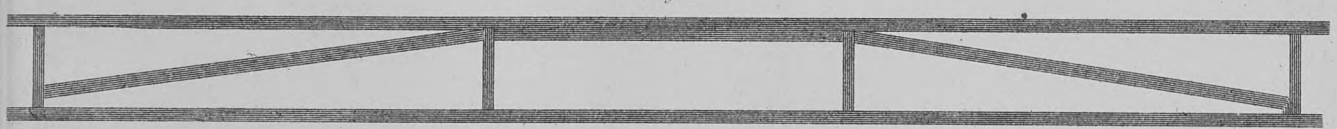


Fig. 6



Drawn by M. A. Nicholson.

Engraved by J. C. Buttre.

ROOF.

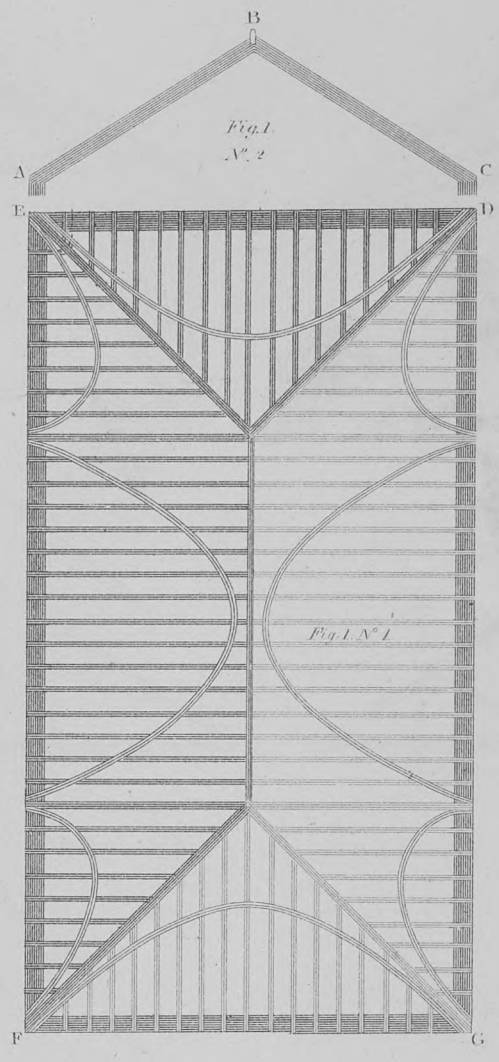


Fig. 1. N°. 2

Fig. 1. N°. 1

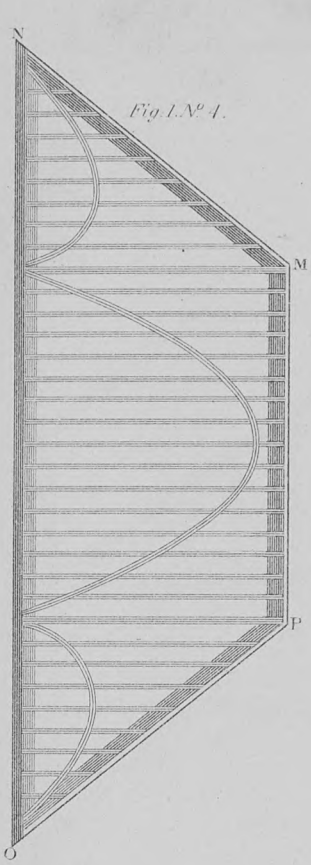


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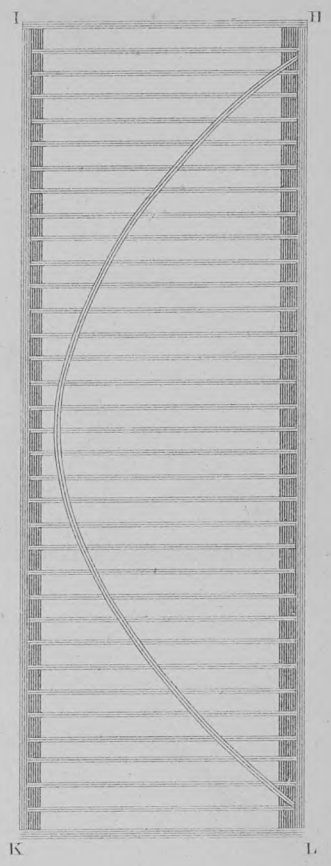


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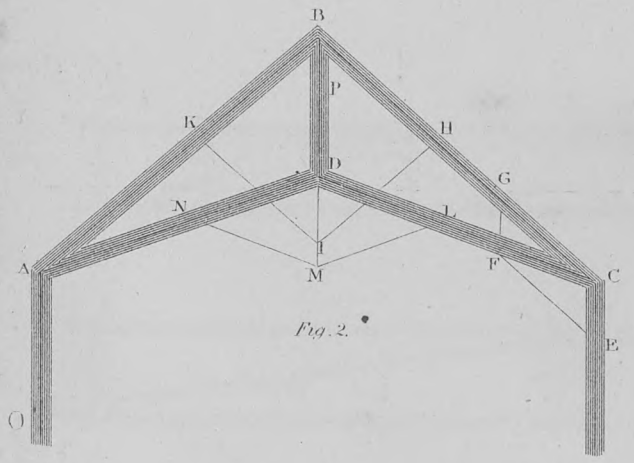


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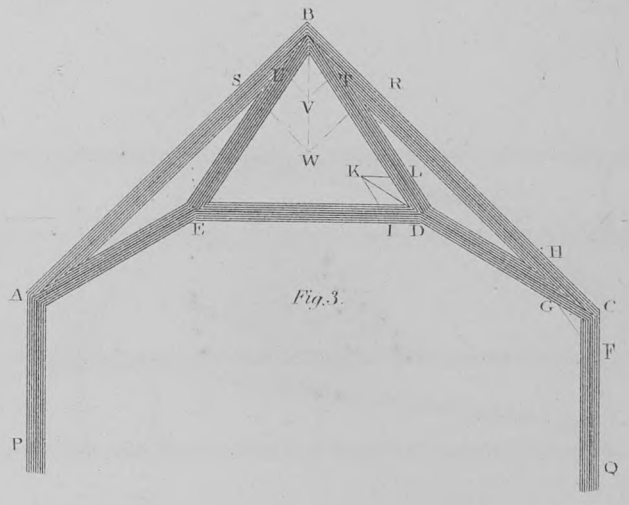


Fig. 3.

Drawn by M. A. Nicholson

Engraved by J. C. Buz

ROOF.

PLATE V.

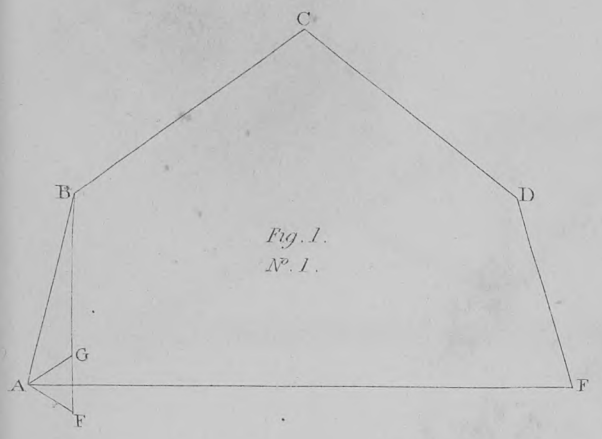


Fig. 1.
N°. 1.

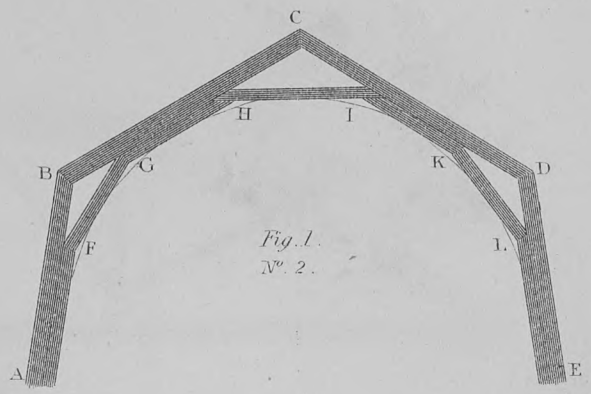


Fig. 1.
N°. 2.

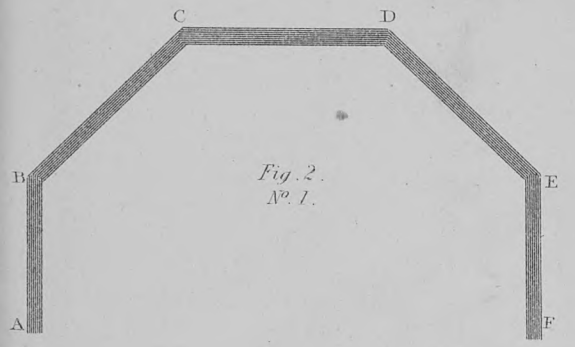


Fig. 2.
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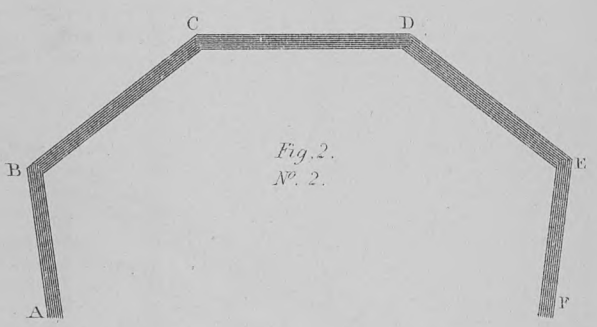


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N°. 2.

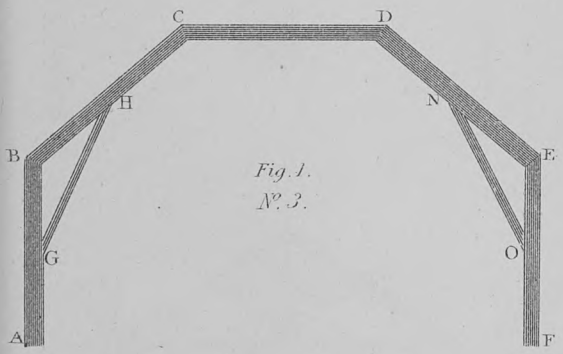


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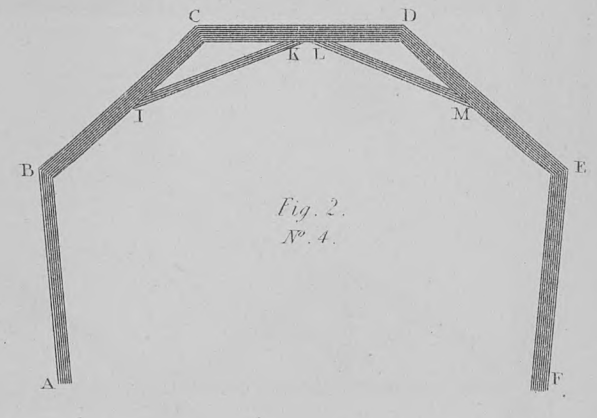


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N°. 4.

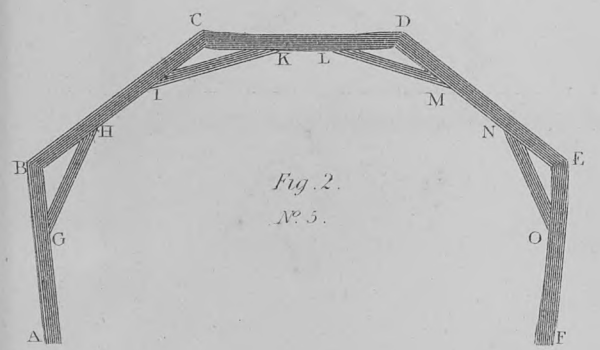


Fig. 2.
N°. 5.

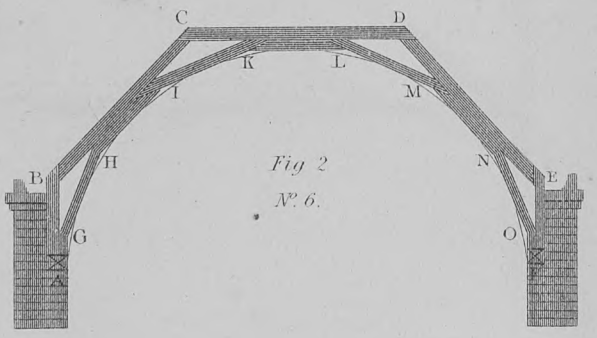


Fig 2
N°. 6.

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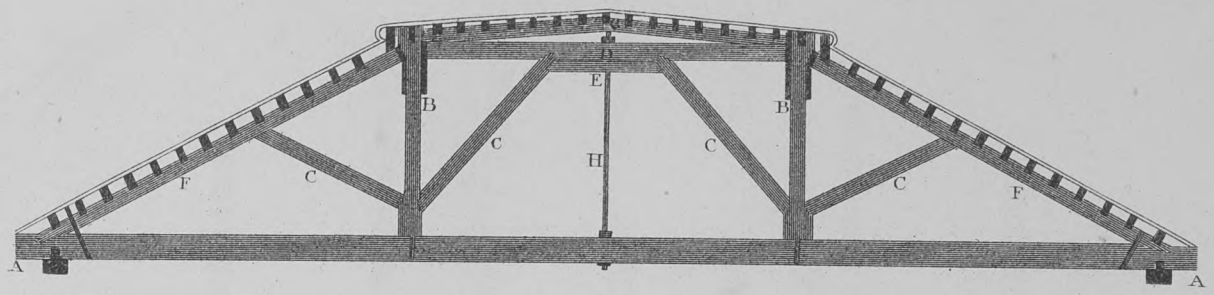


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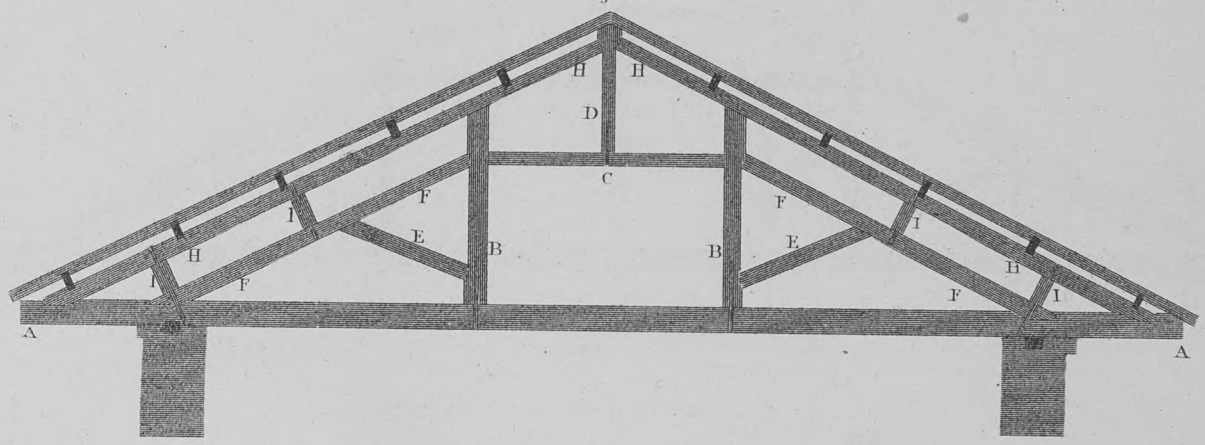
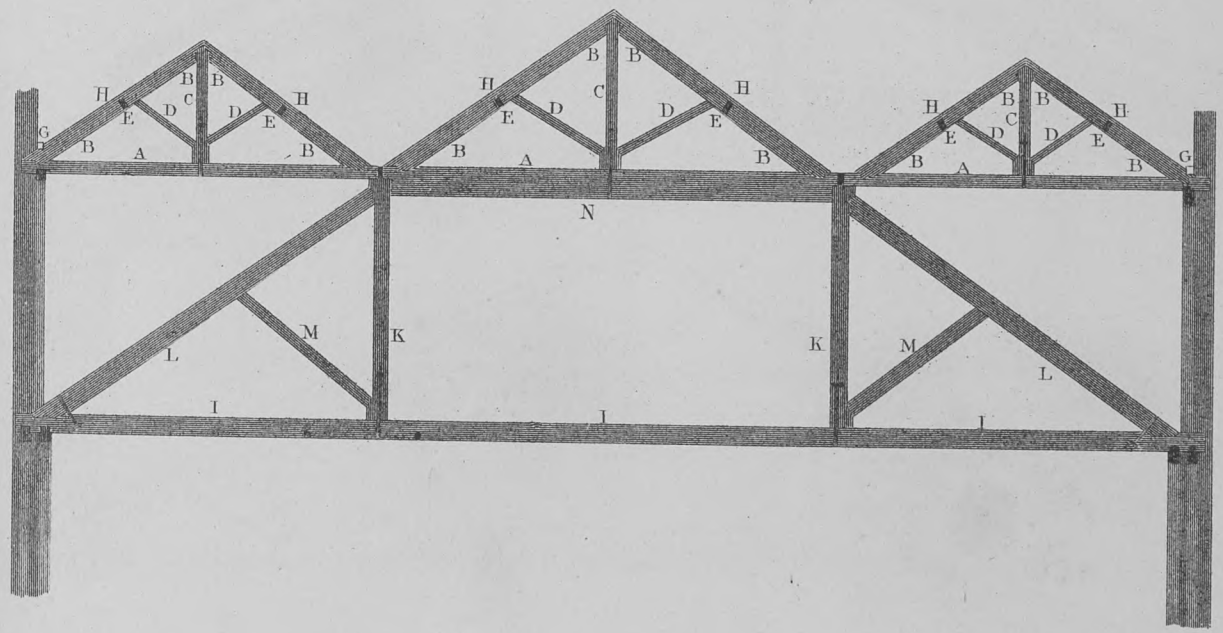


Fig. 3.



Drawn by M.A. Nicholson.

Engraved by J.C. Buttr

ROOFS.

FROM COVENT GARDEN THEATRE.

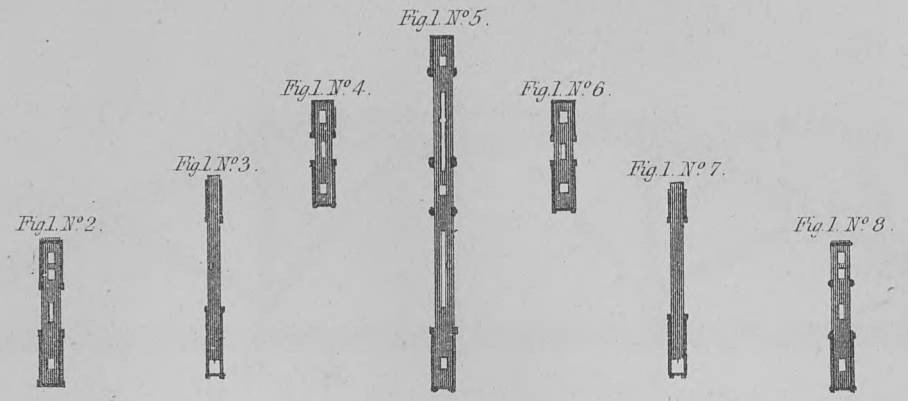
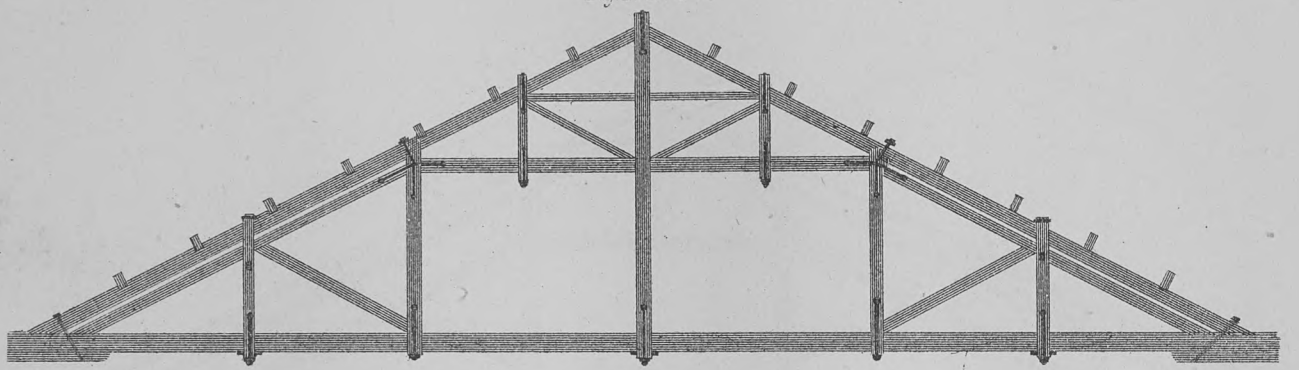


Fig.1. N°1.



FROM DRURY LANE THEATRE.

Fig.2. N°2.

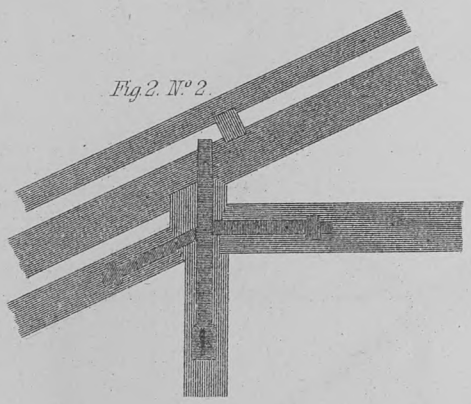


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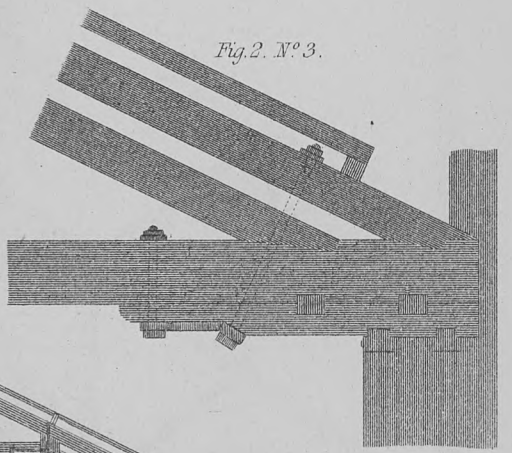
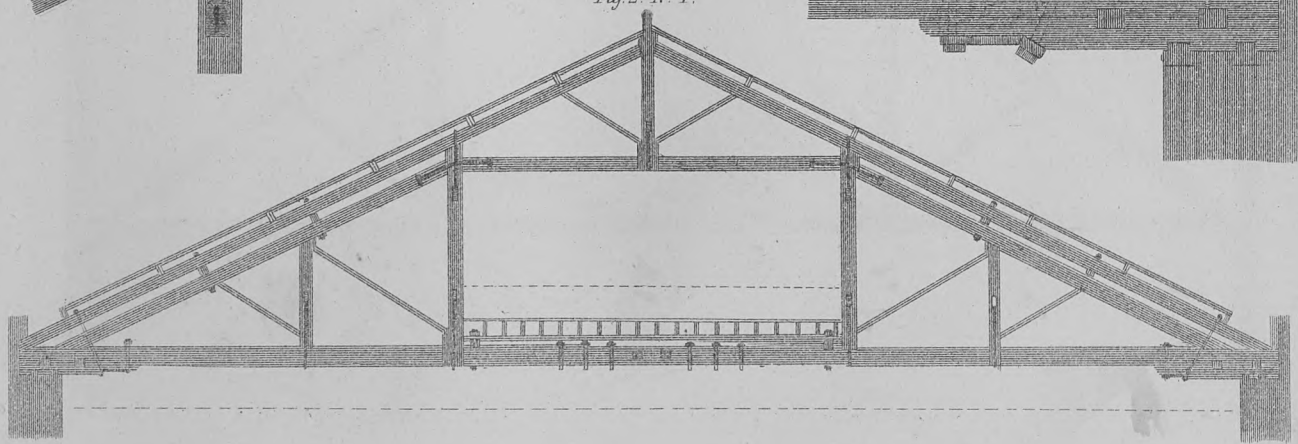


Fig.2. N°1.



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Engraved by J.C. Buttre.

Fig. 1. N° 2.

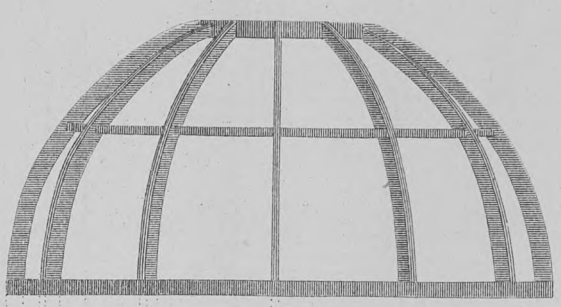


Fig. 3. N° 2

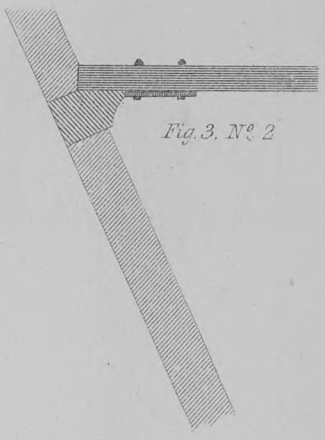


Fig. 1. N° 1.

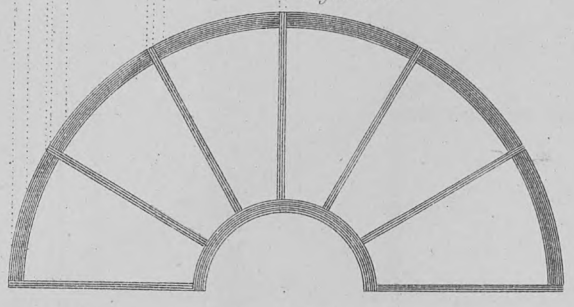


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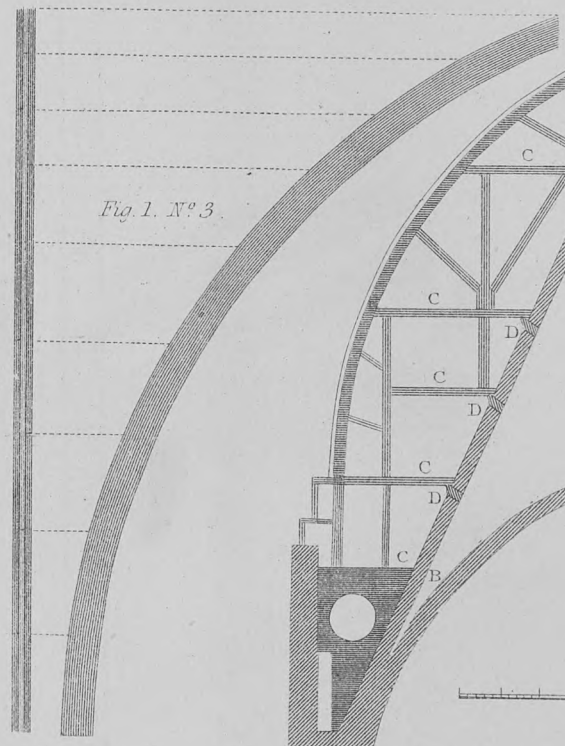
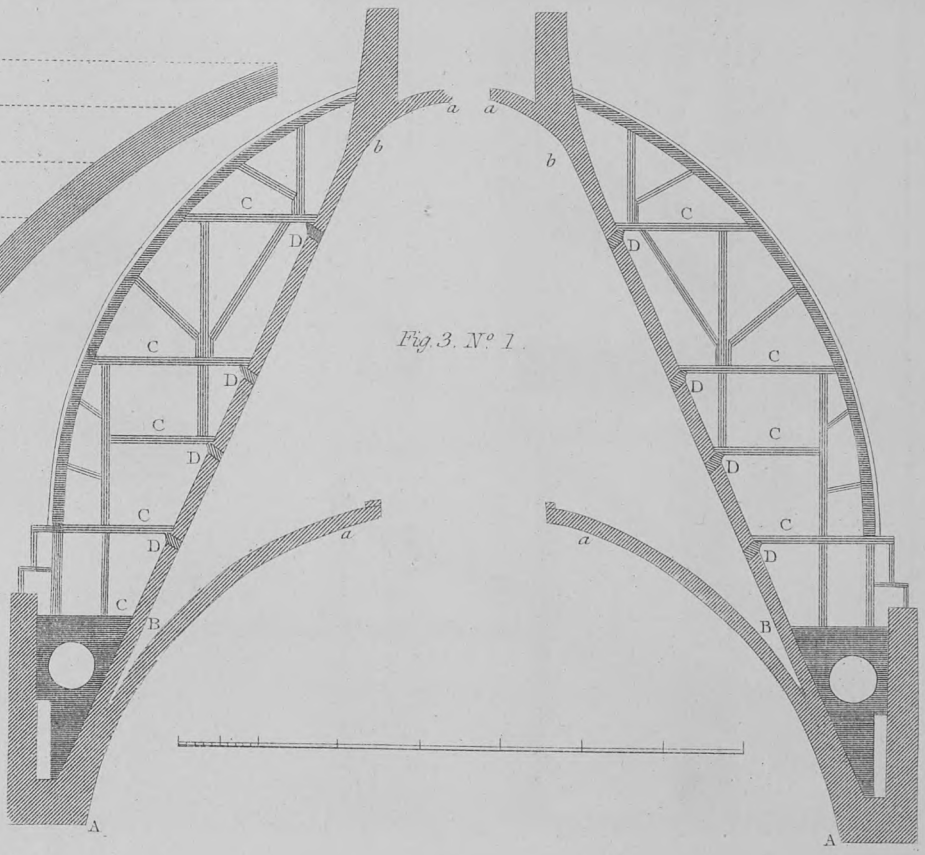


Fig. 3. N° 1.



Drawn by P. Nicholson.

Engraved by J.C. Buttre.

SASHES.



n by P.Nicholson.

Engraved by J.C.Buttre.

Fig. 1. N°1.

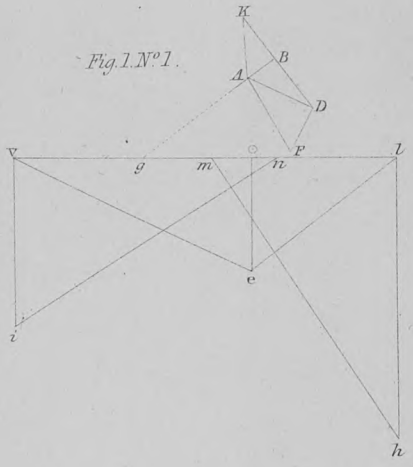


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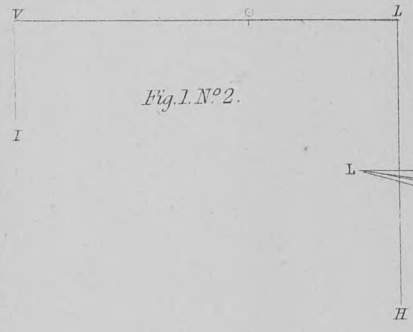


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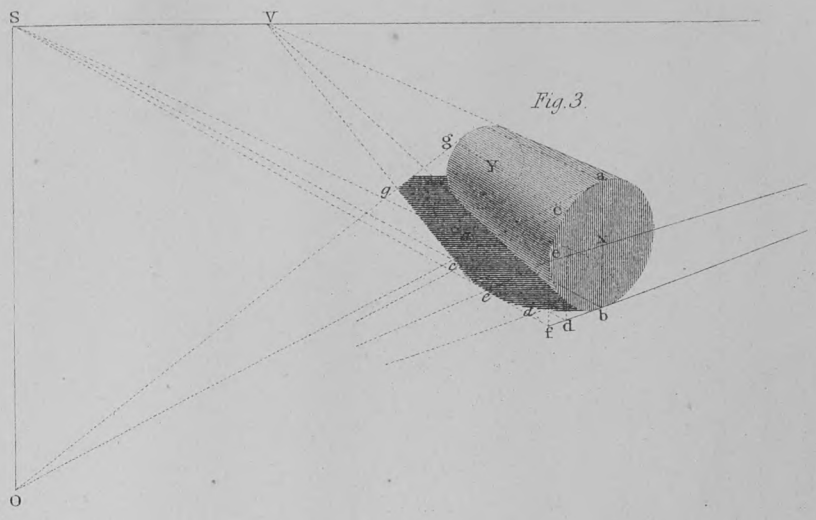


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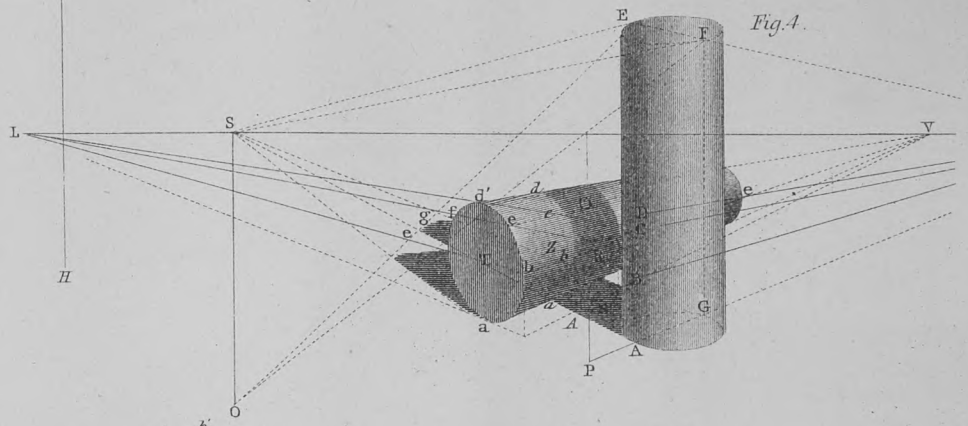
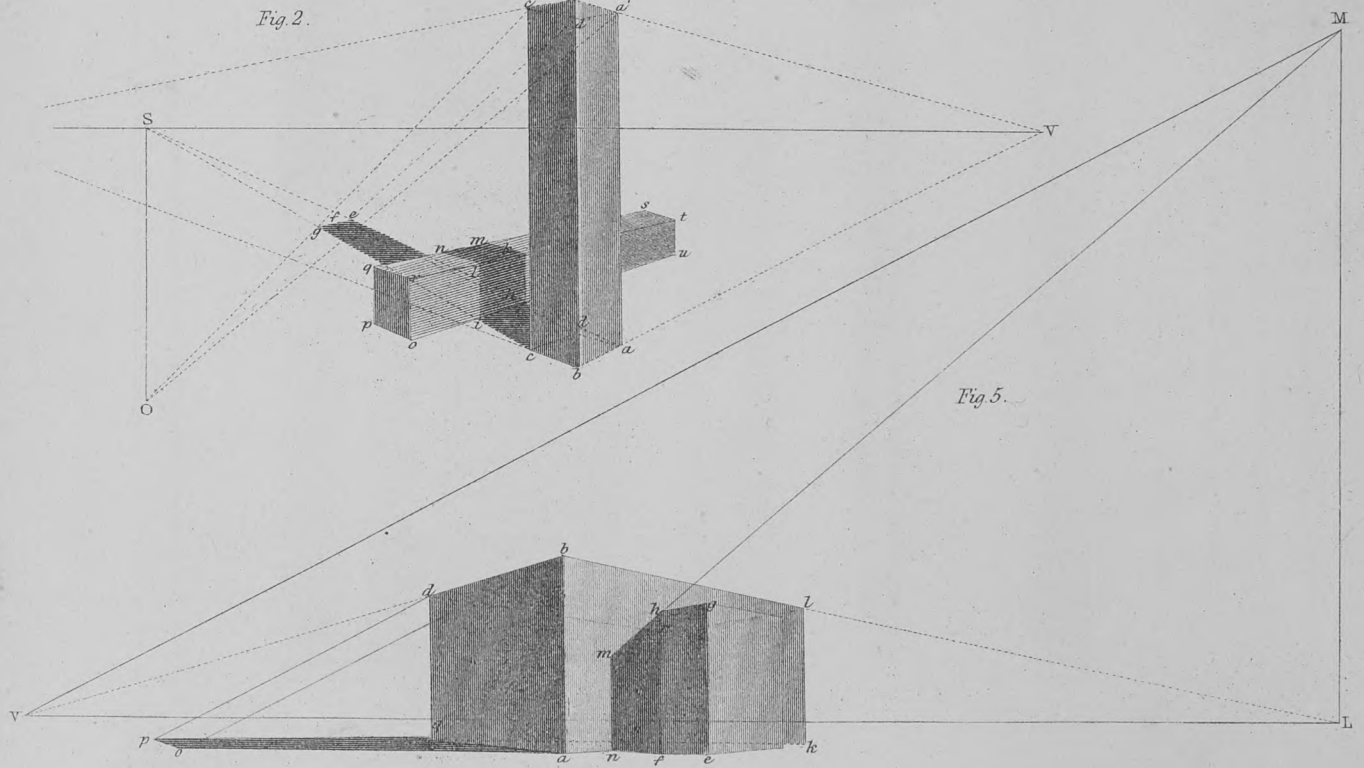


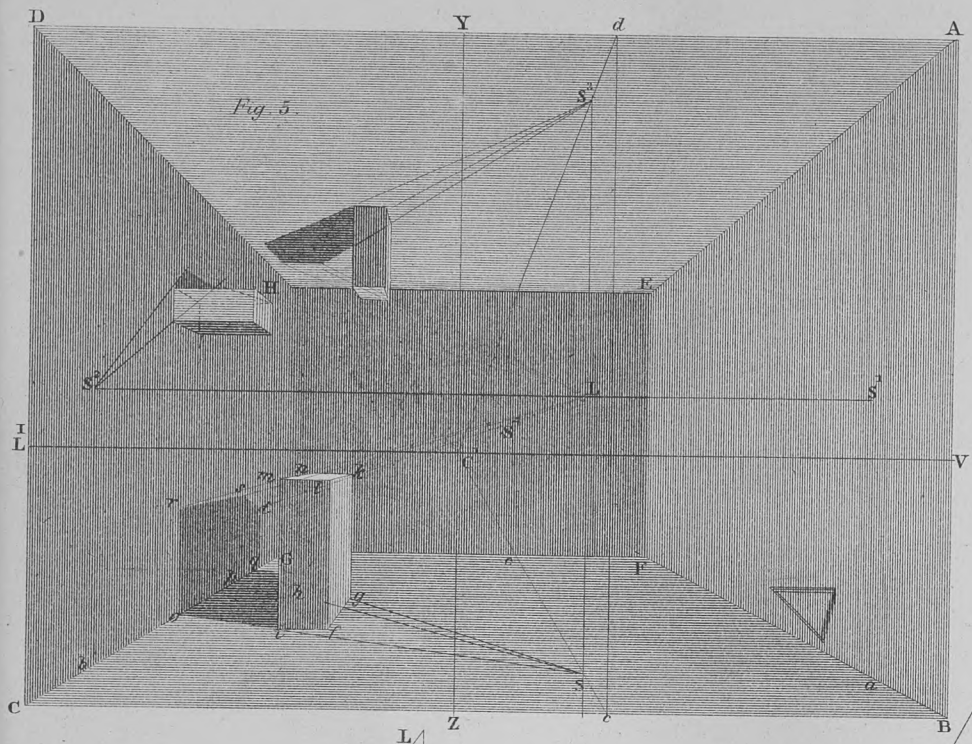
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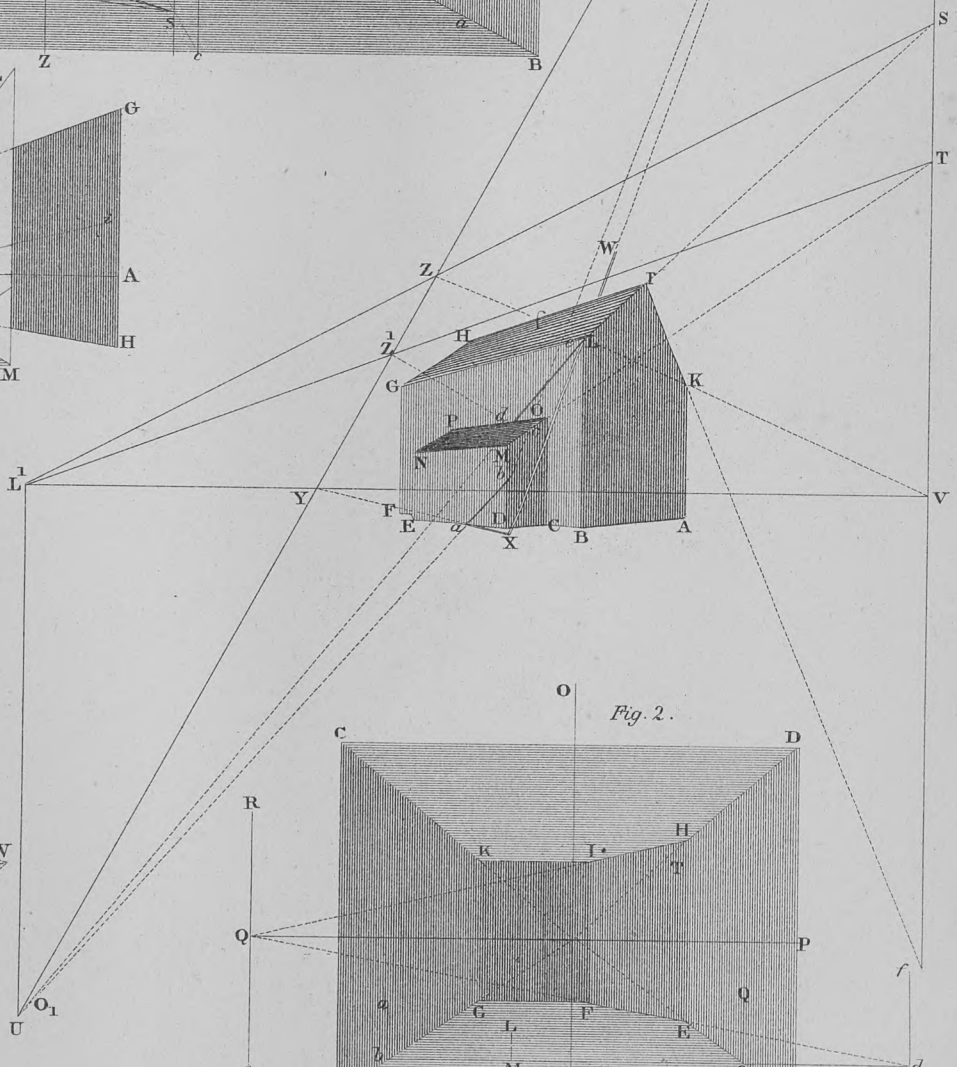
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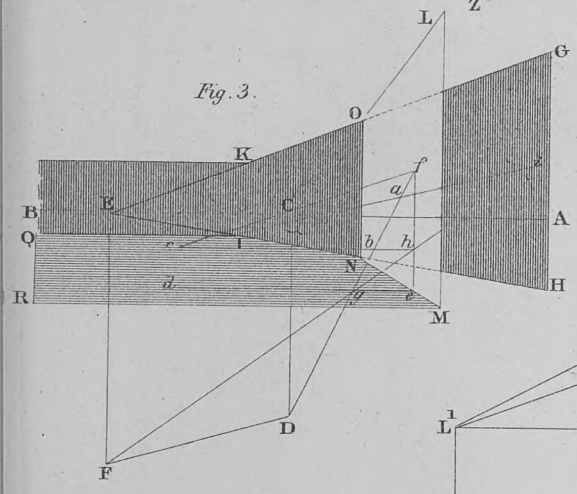


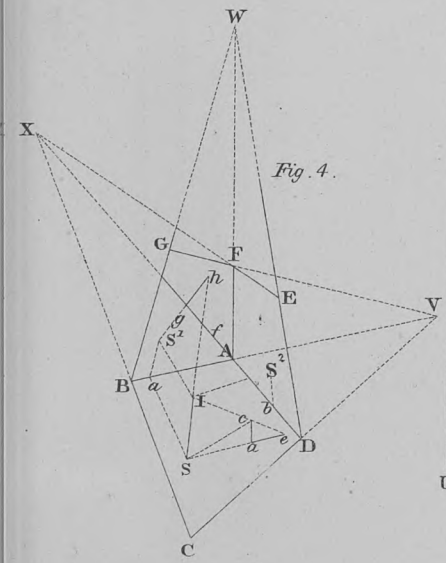
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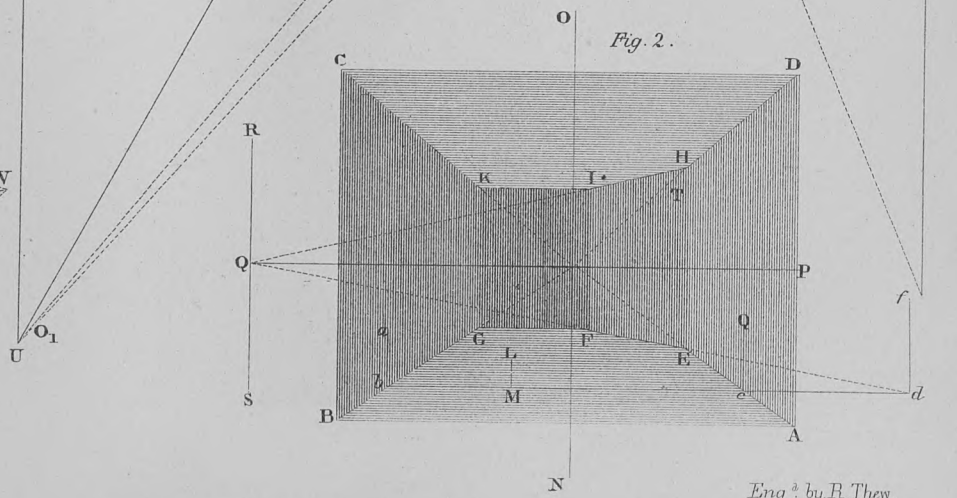
Engraved by J.C.Bu


Fig. 5.
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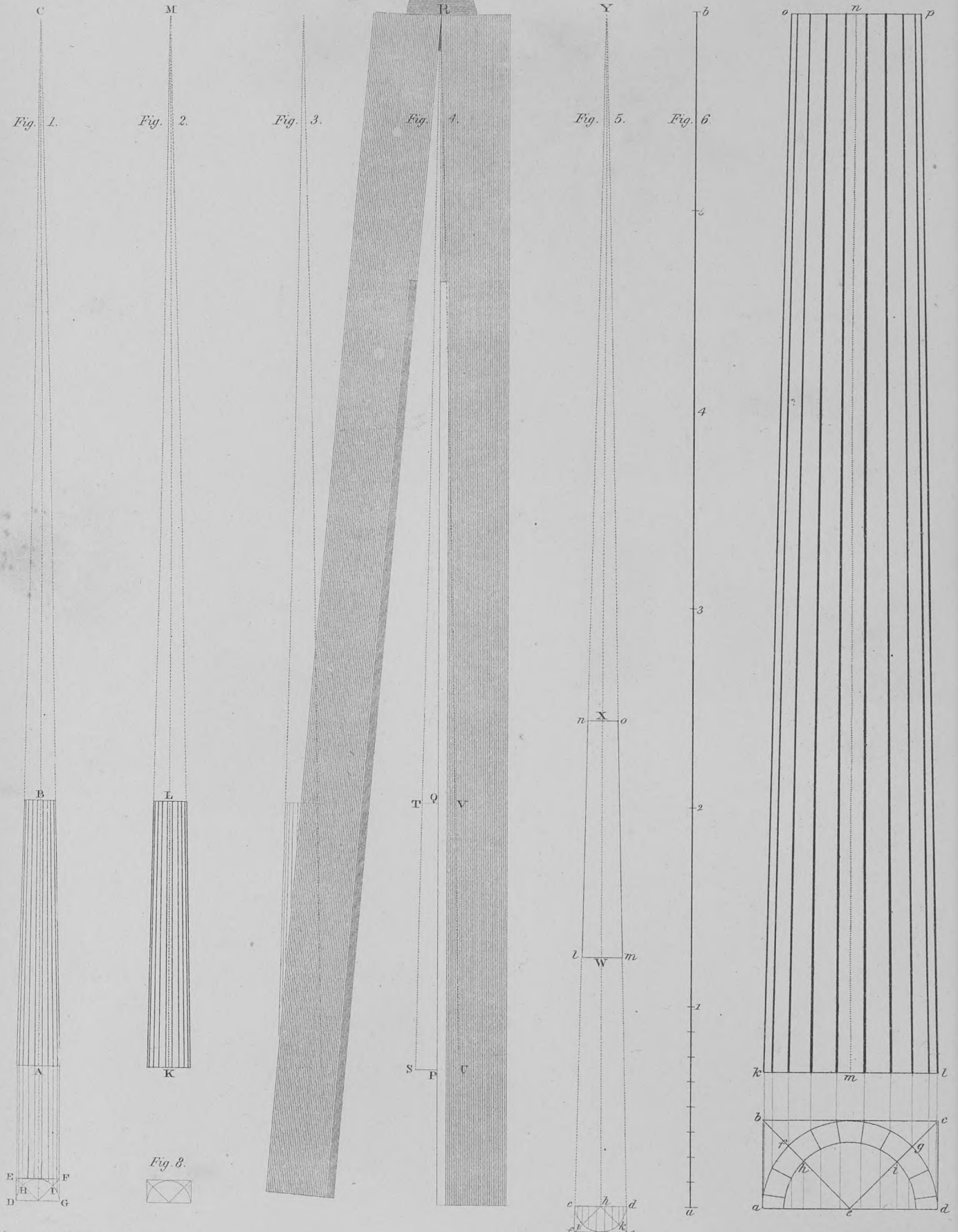

Fig 1.
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Fig. 3.
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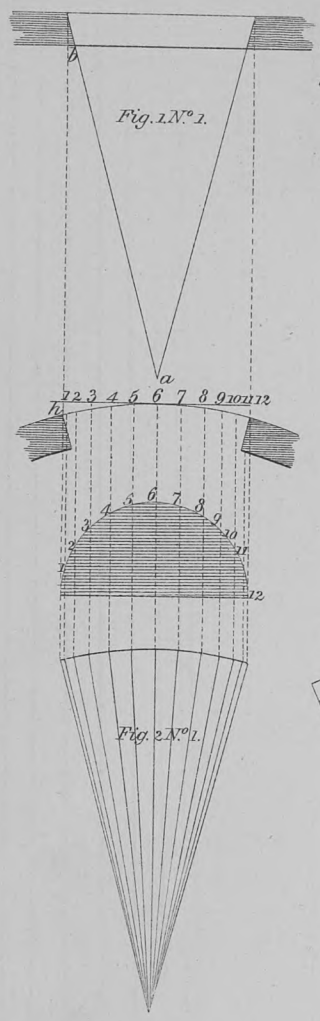

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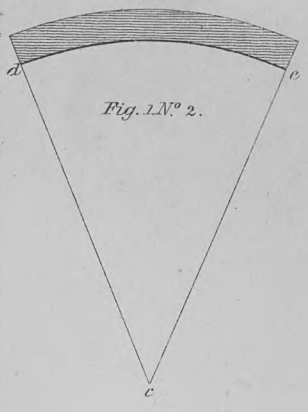

Fig. 2.
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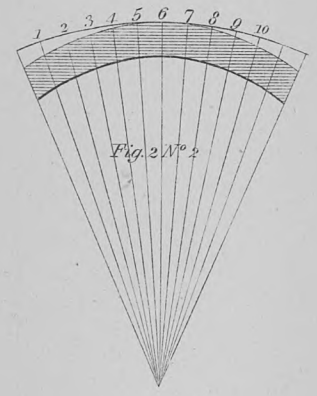
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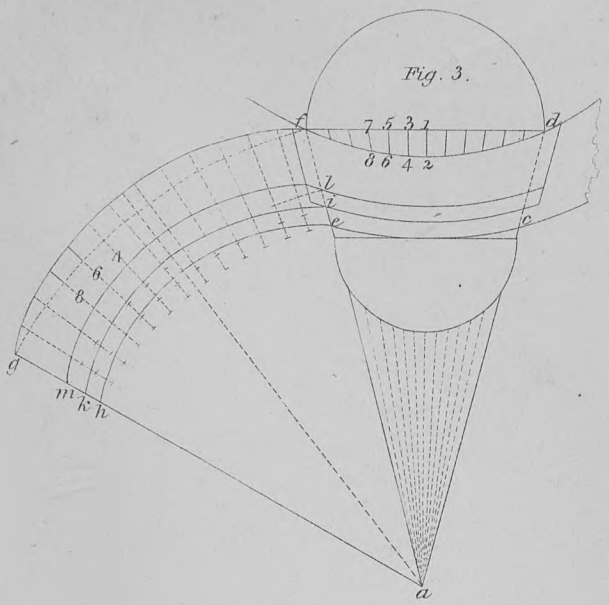


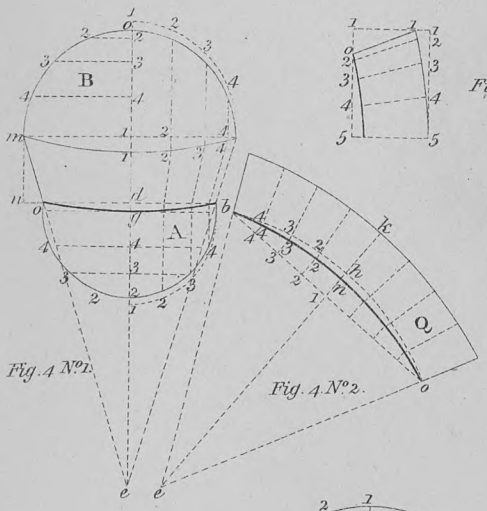
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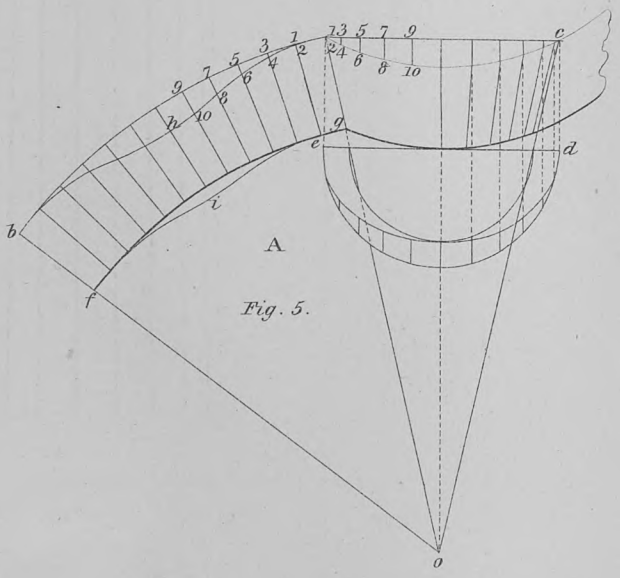


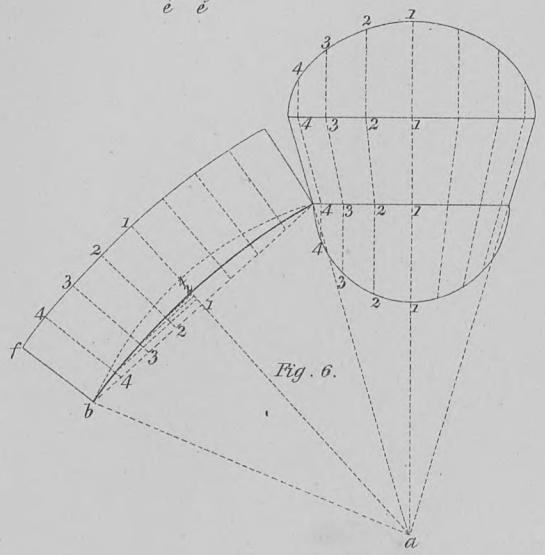












Eng.d by . R . Thew .

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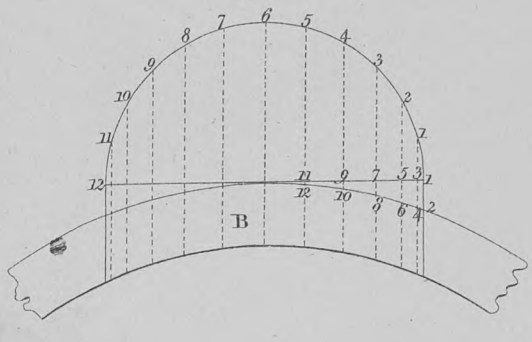


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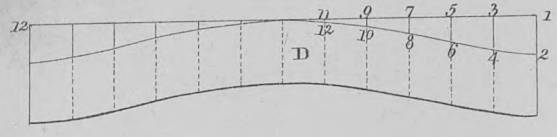


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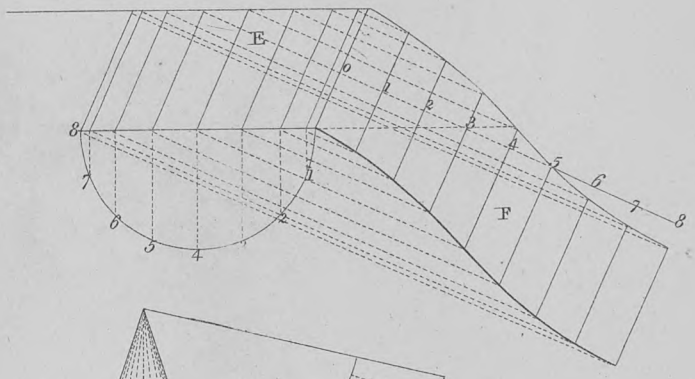


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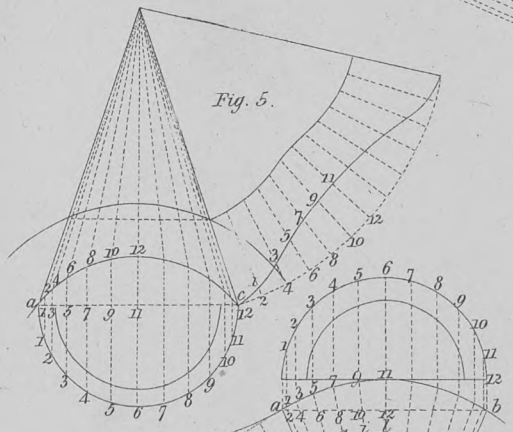


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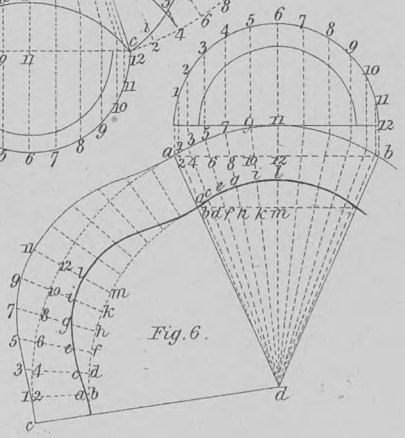


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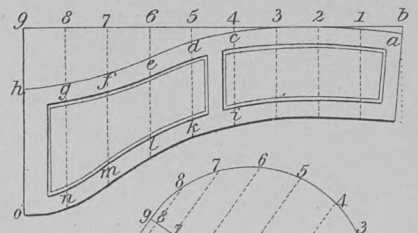


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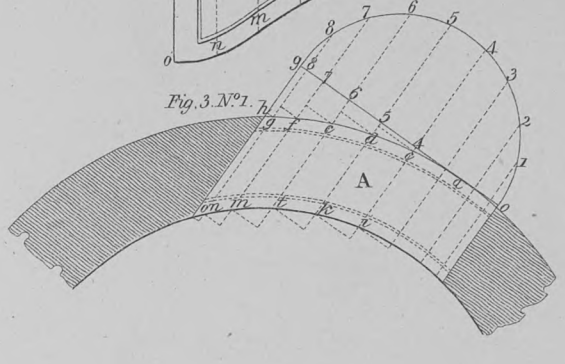


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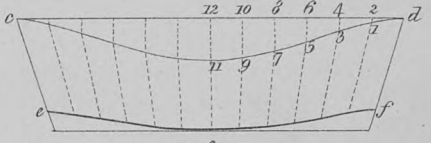


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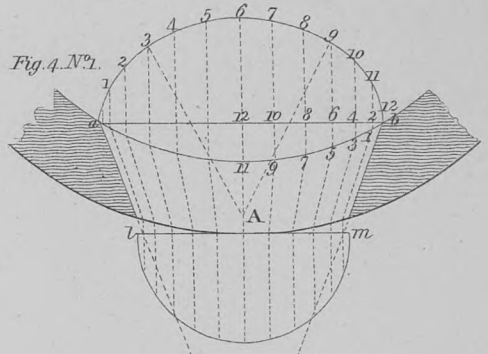


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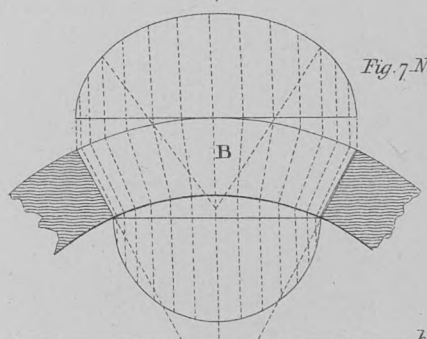
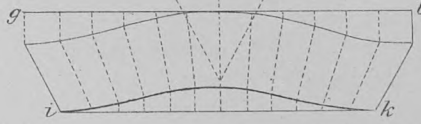


Fig 7 N°2



Engd by. R. Thew.

SPANDREL BRACKETING

ANGLE BRACKETS

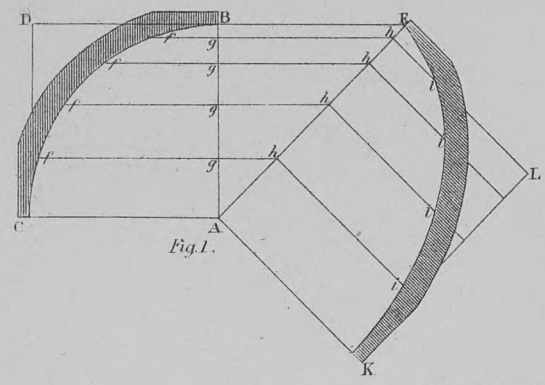


Fig.1.

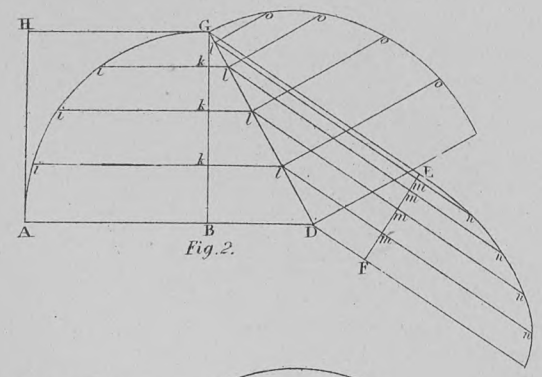


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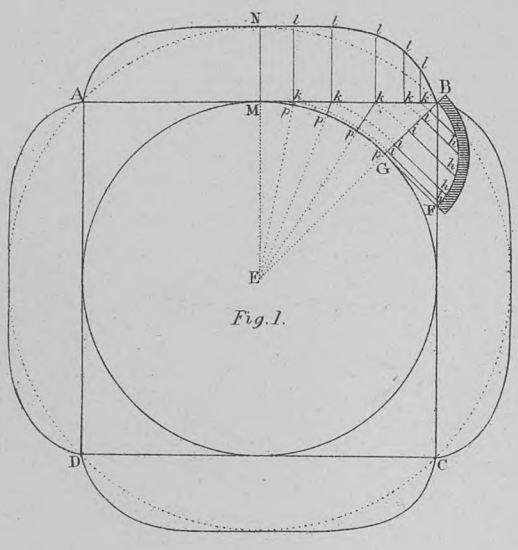


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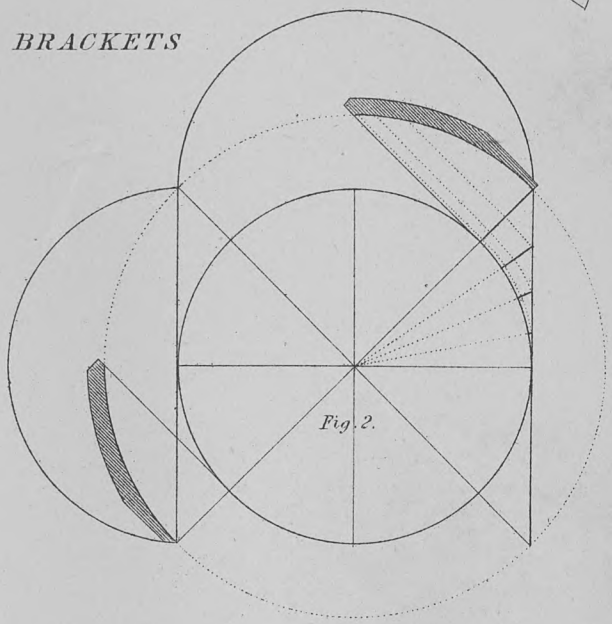


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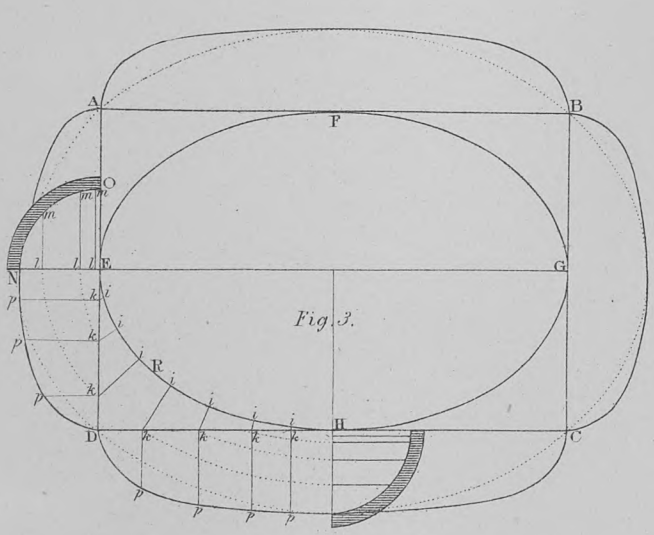


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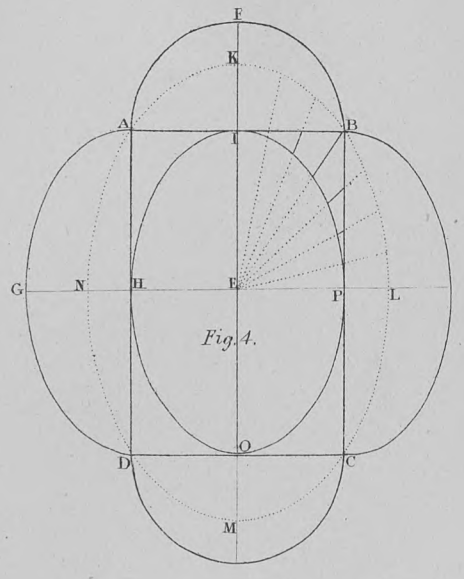


Fig.4.

Drawn by P. Nicholson

Engraved by J C Butt

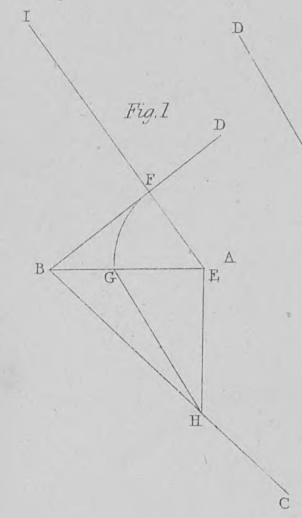


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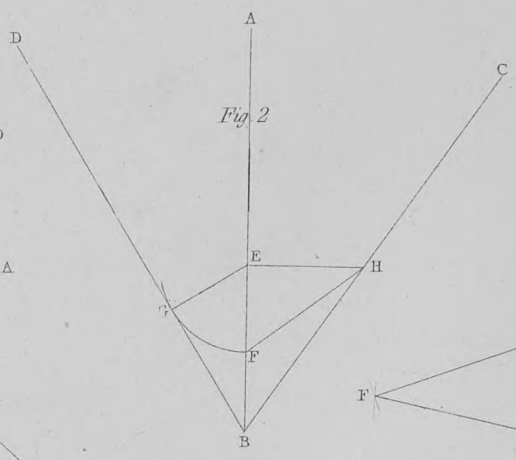


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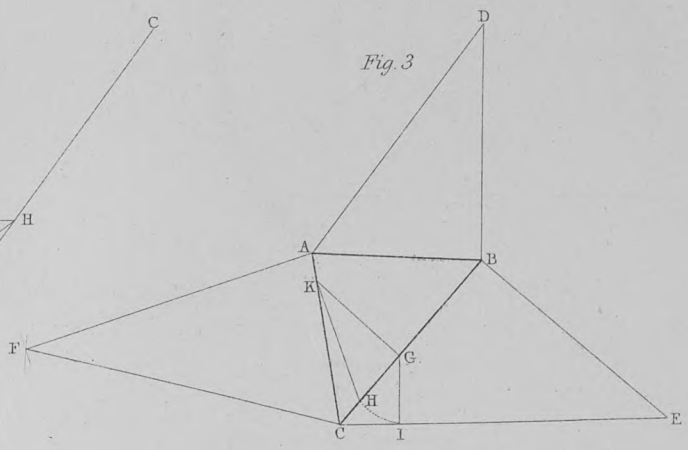


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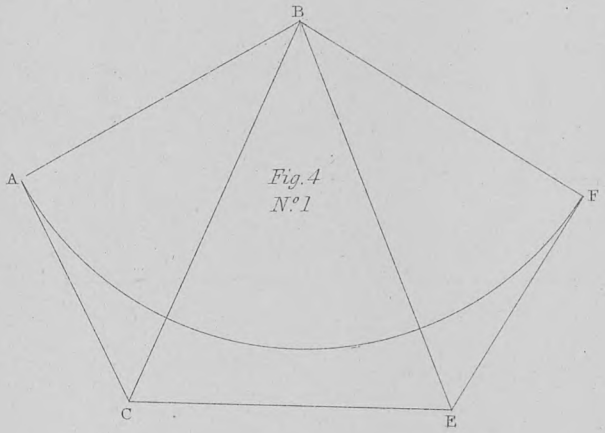


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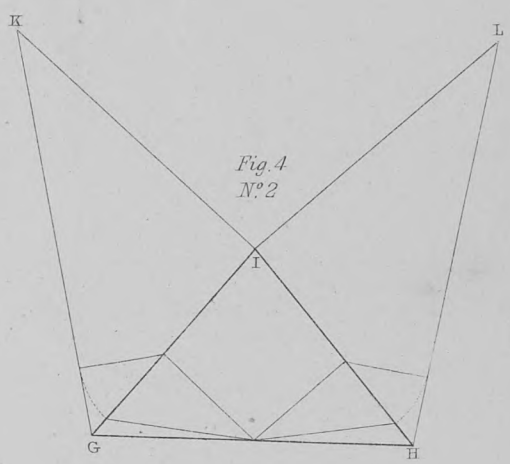


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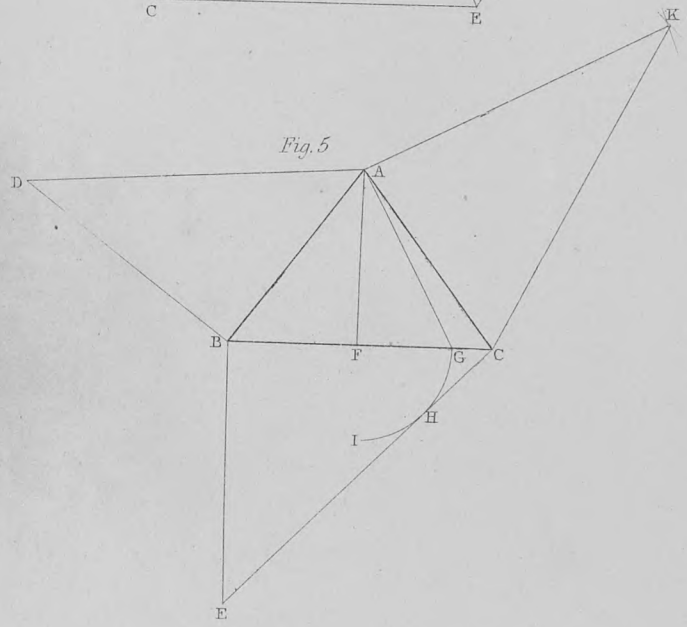


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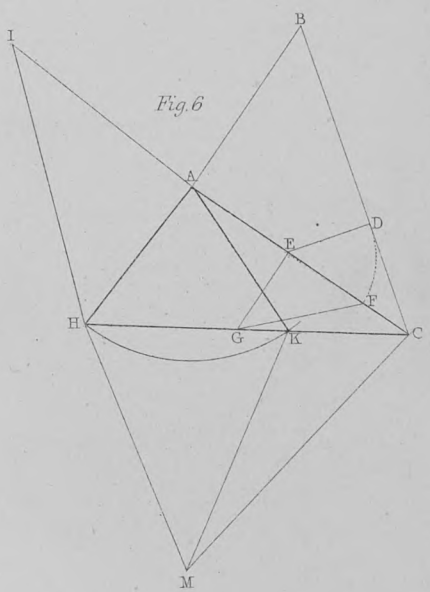


Fig. 6

STEREOTOMY.

Fig. 7

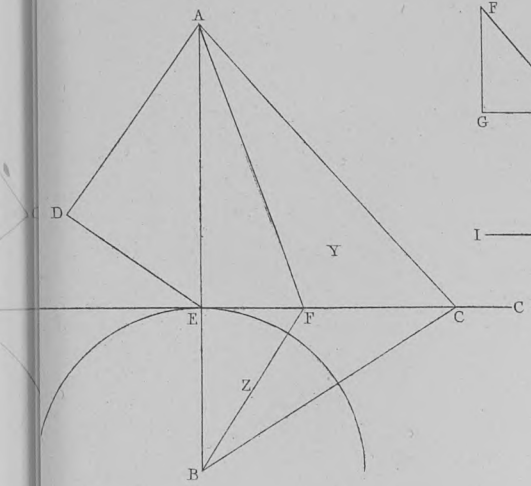


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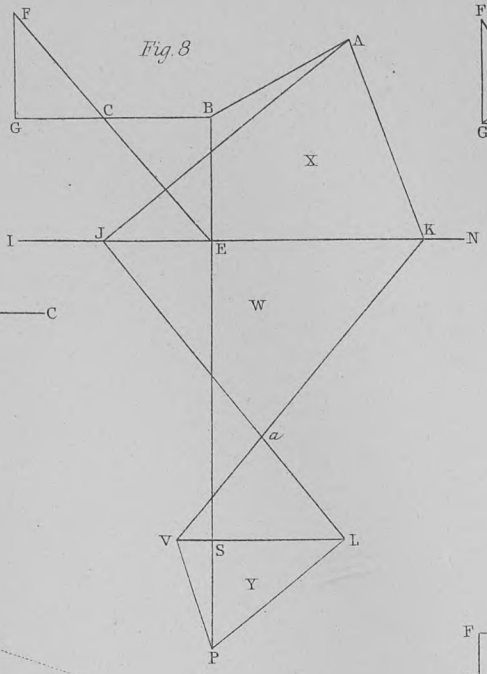


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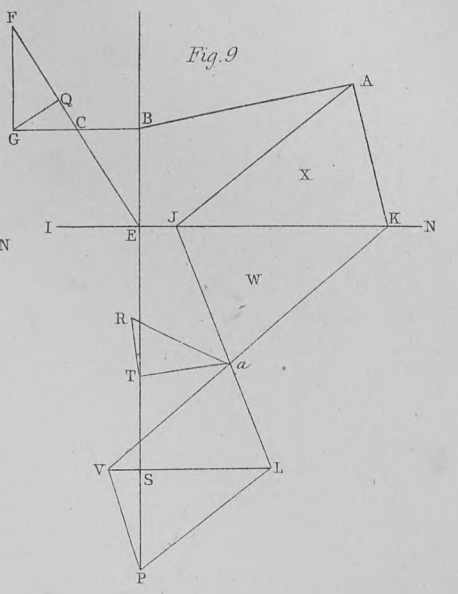


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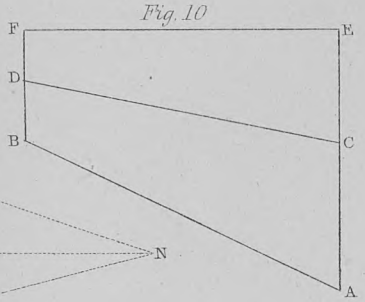


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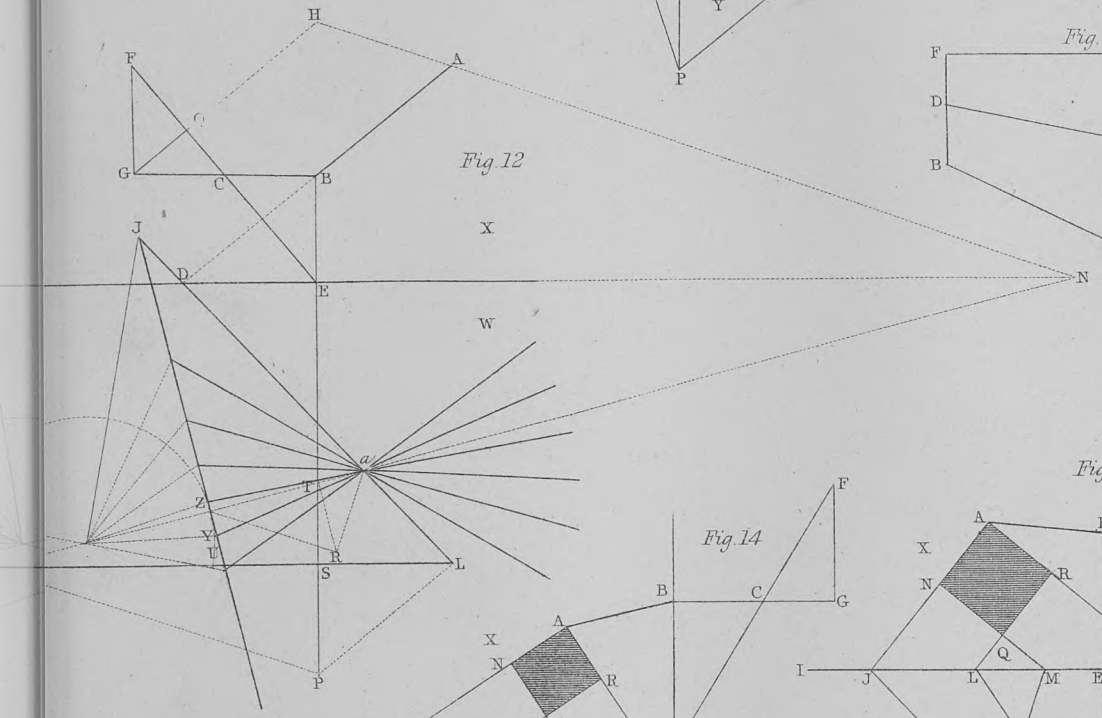


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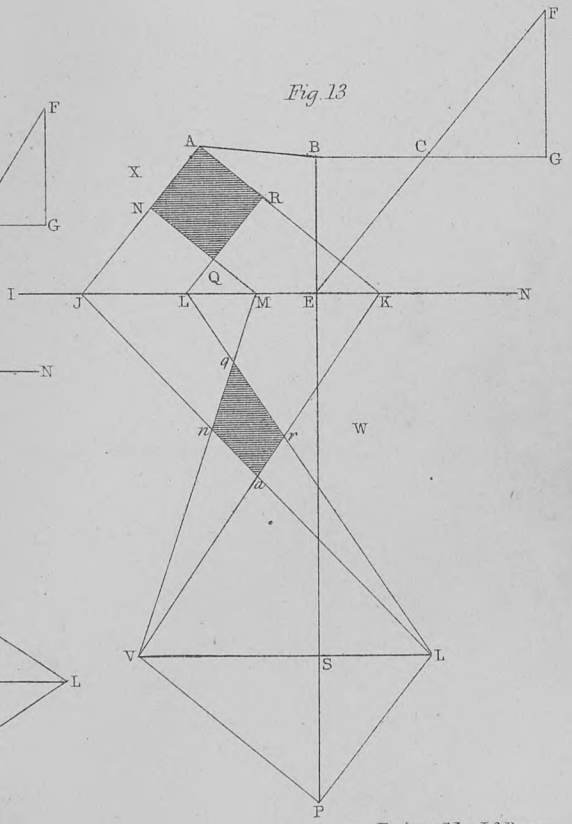


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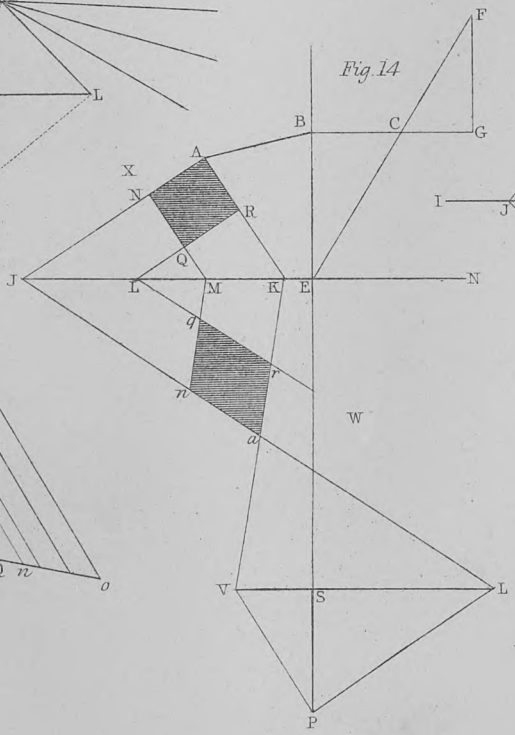
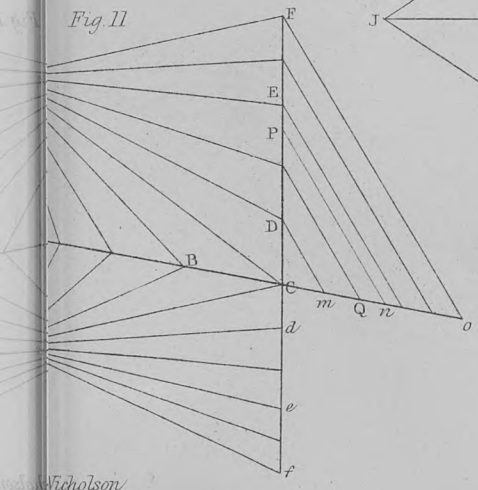


Fig. 11



Nicholson.

Engraved by J.C.Buttre.

STEREOTOMY.

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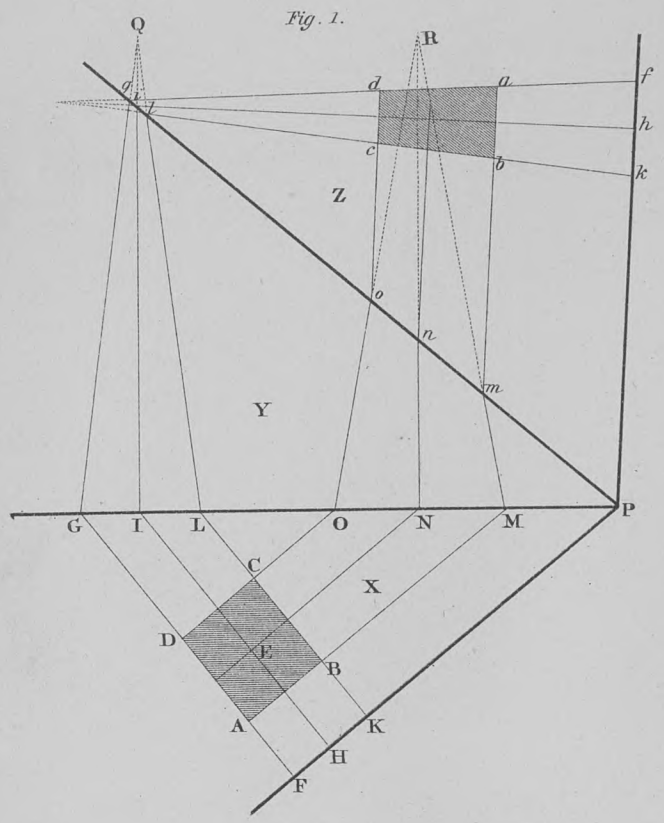


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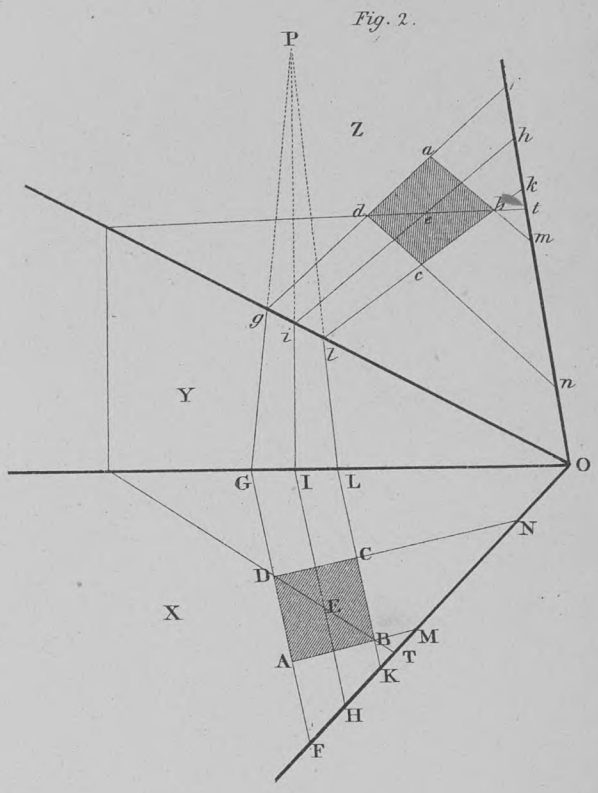


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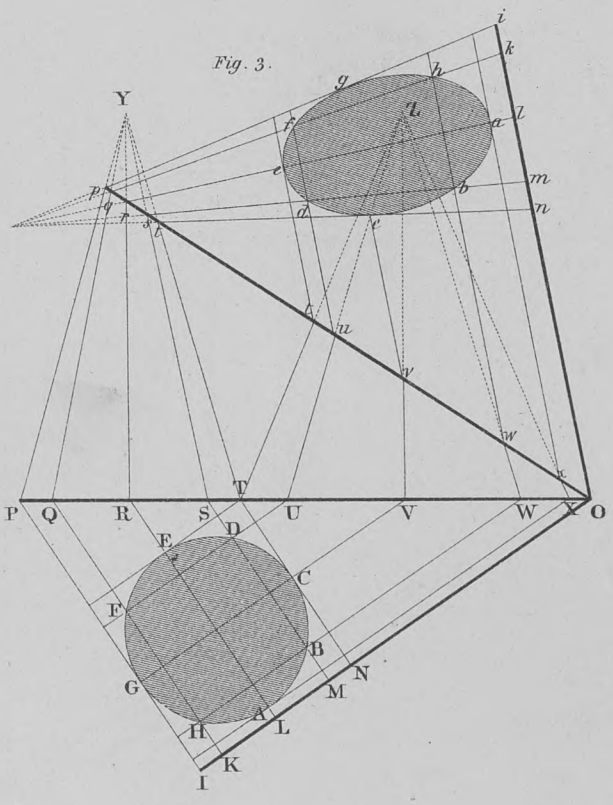
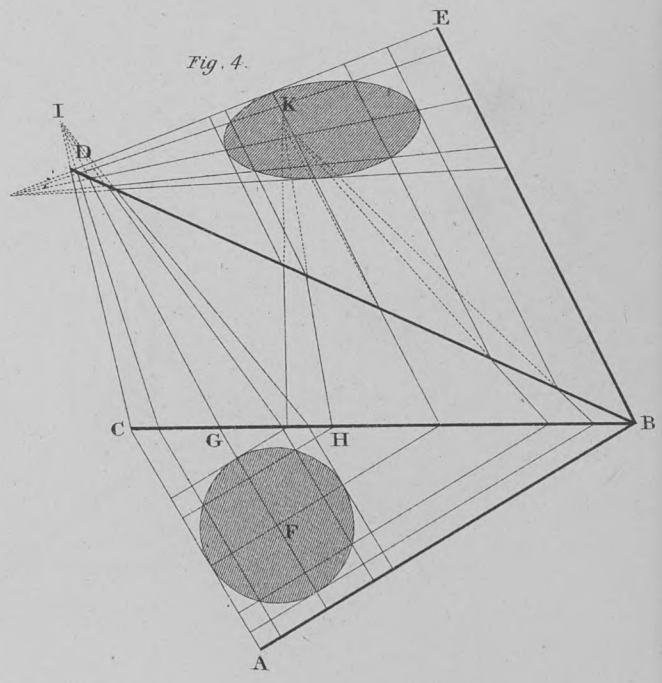


Fig. 4.



Invented & Drawn by P. Nicholson.

Engᵈ by R. Thew.

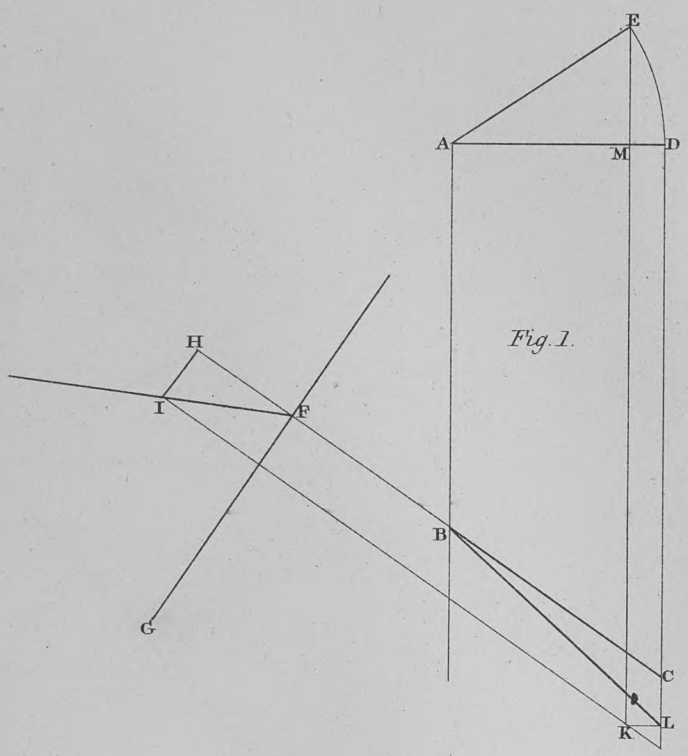


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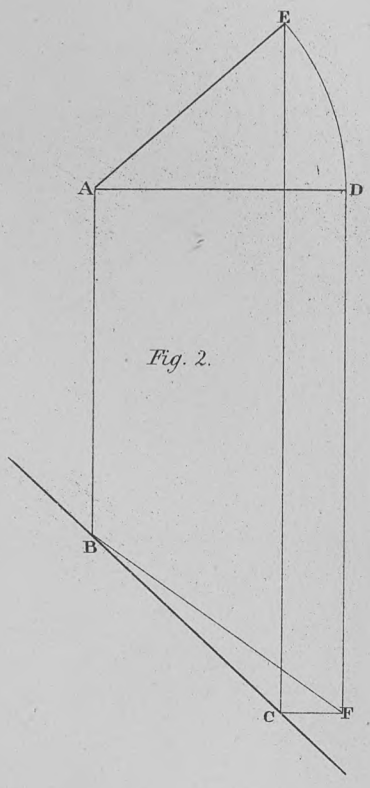


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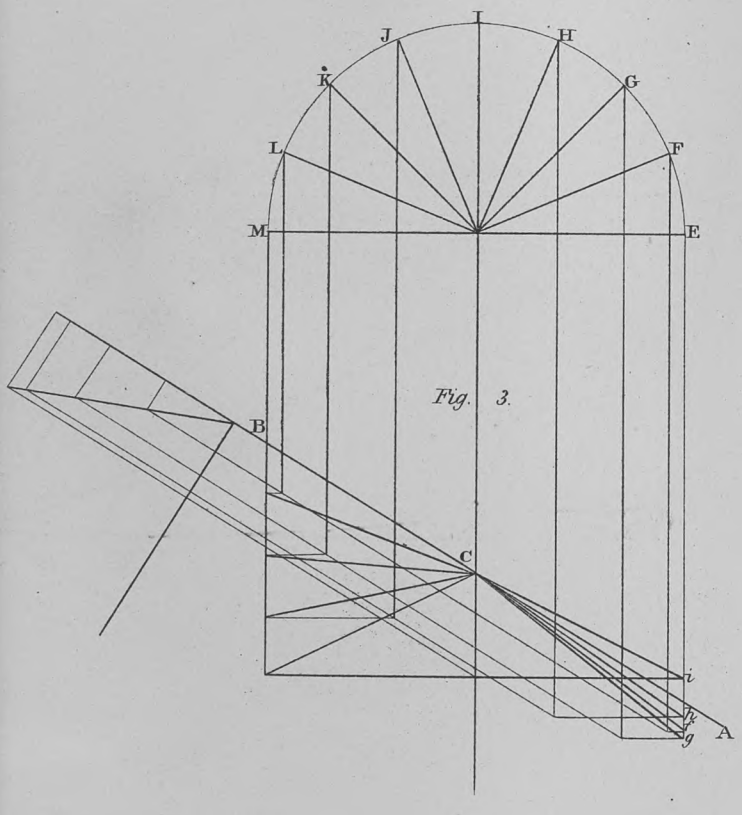


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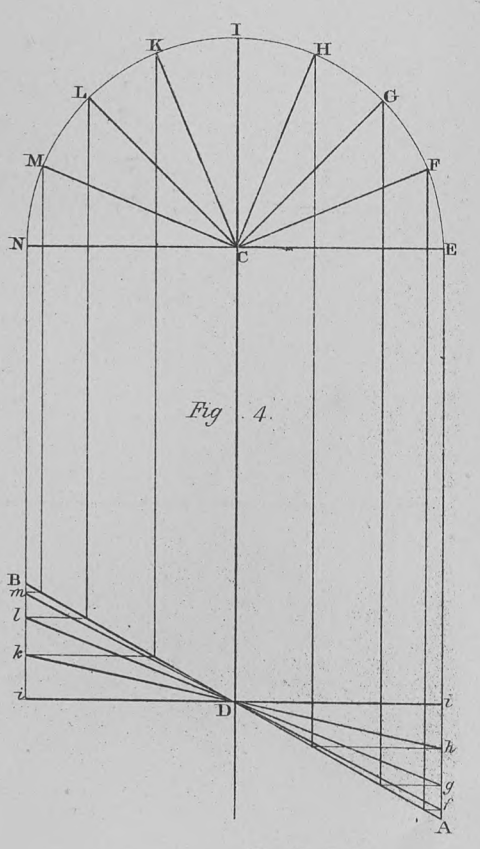
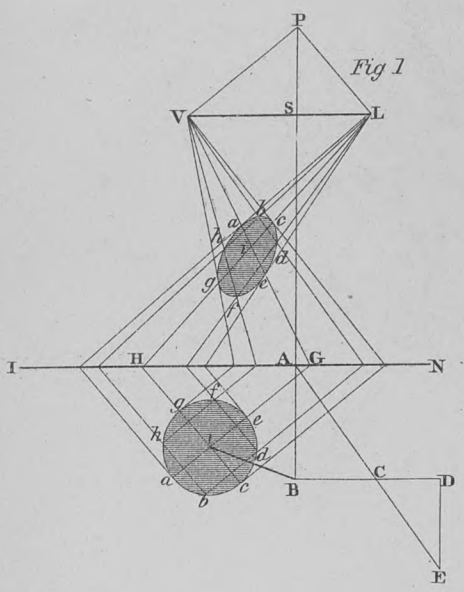
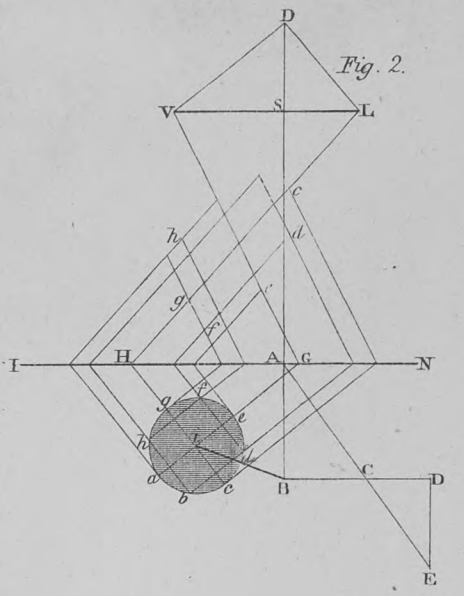


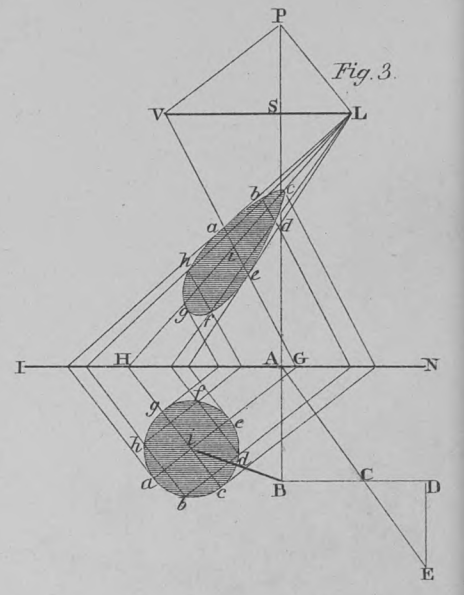
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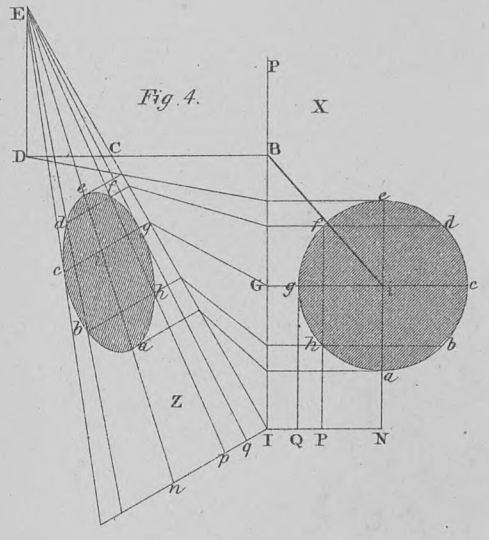
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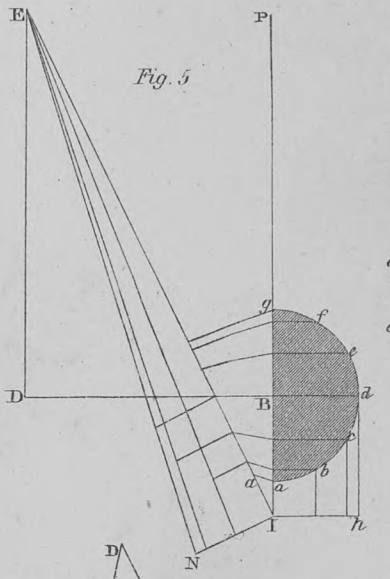
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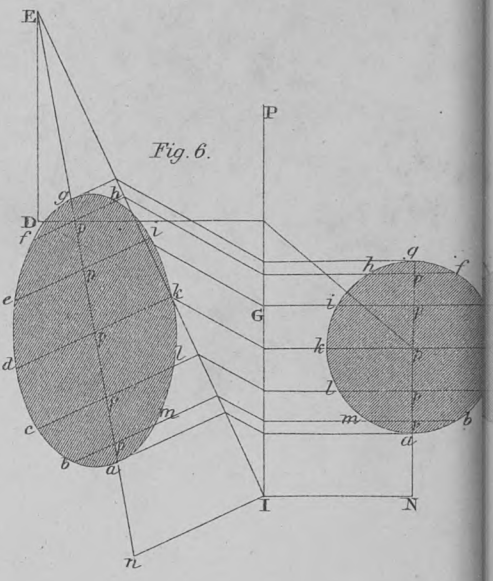


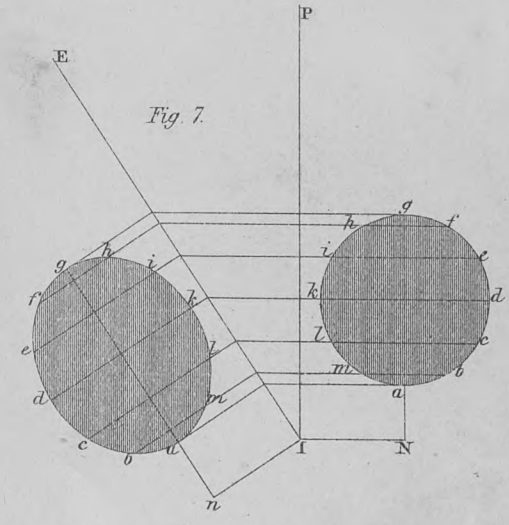


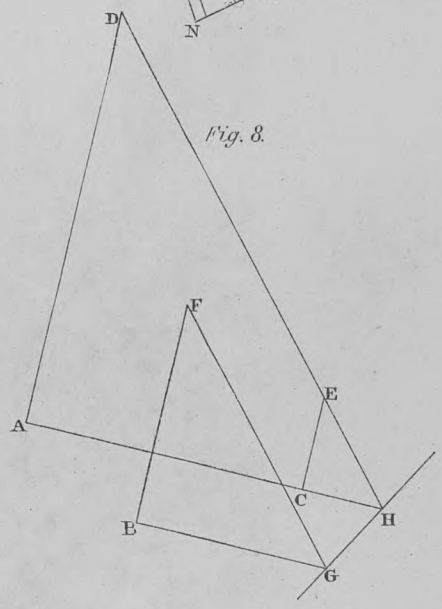


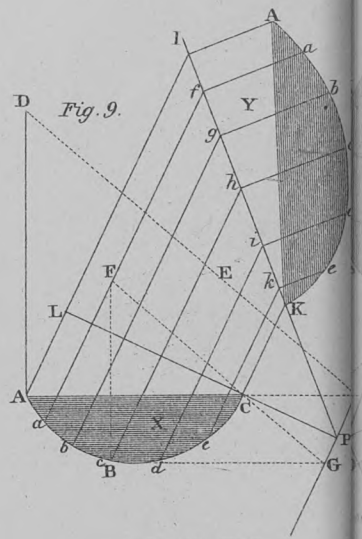












Drawn by P. Nicholson.

Engd by R. Thew.

Fig. 3.

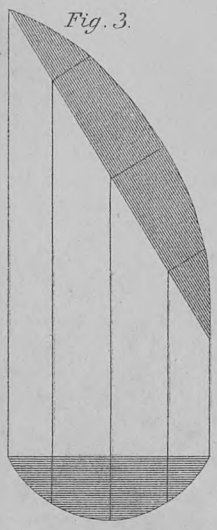


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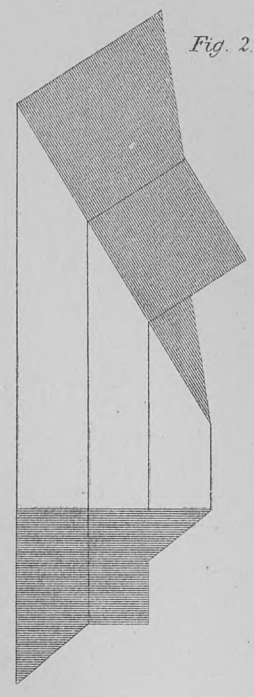


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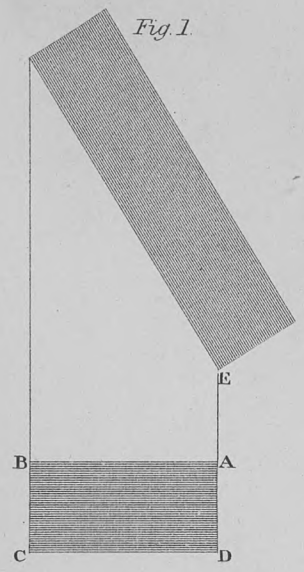


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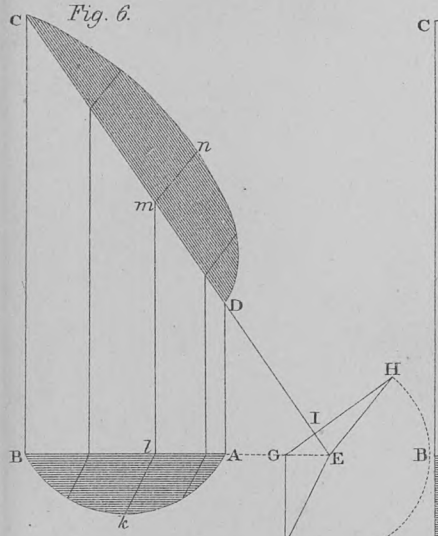


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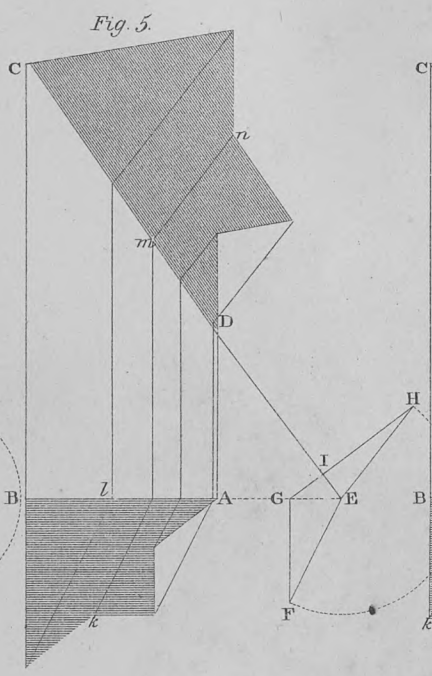
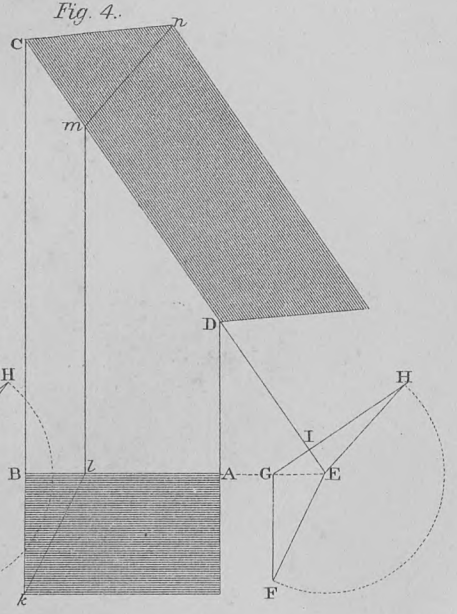


Fig. 4.



Drawn by P. Nicholson.

Engd by B. Thew.

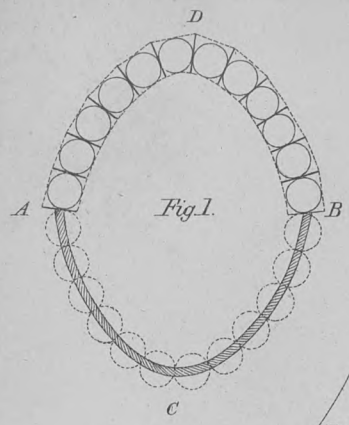


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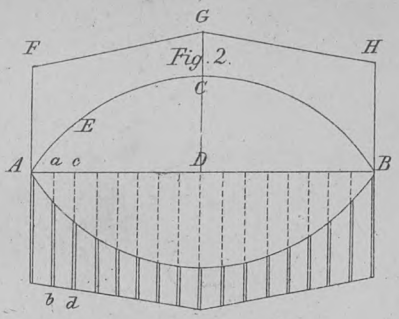


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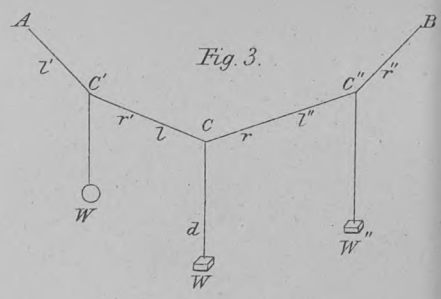


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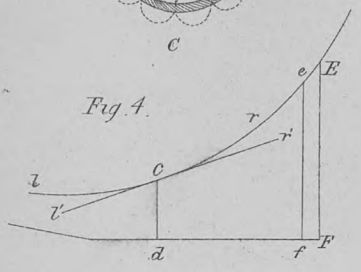


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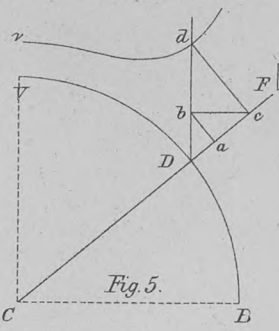


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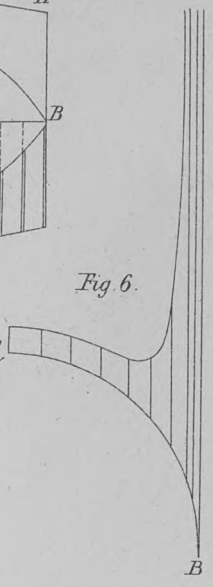


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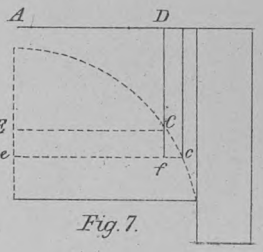


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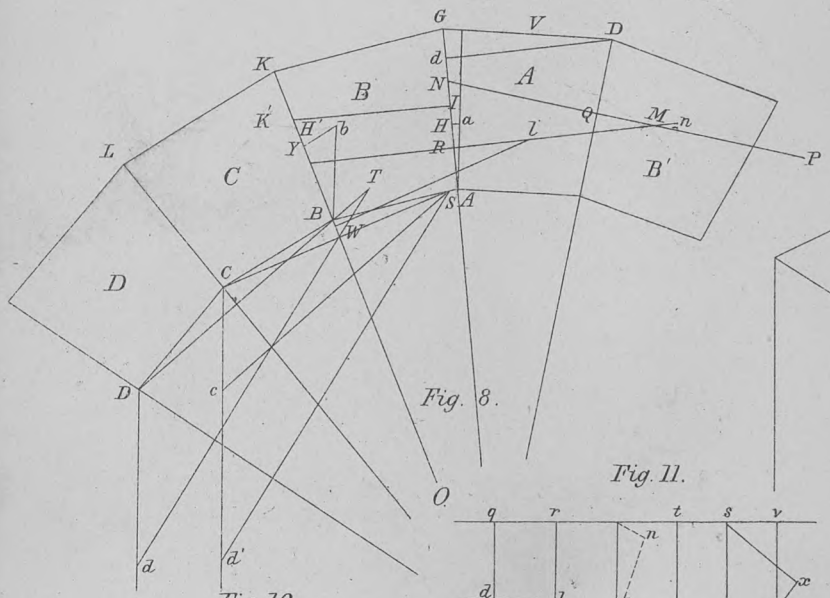


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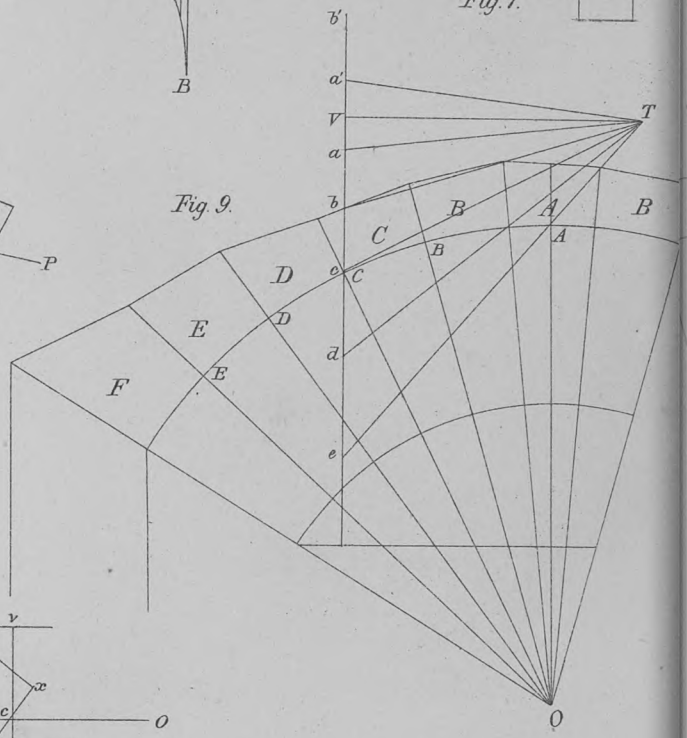


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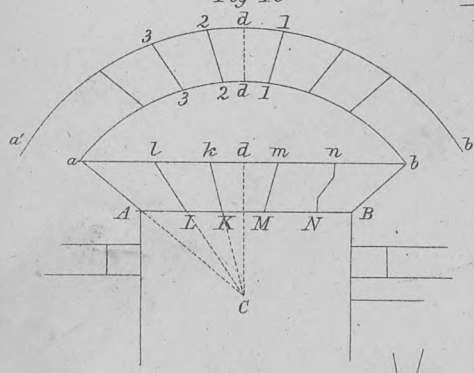


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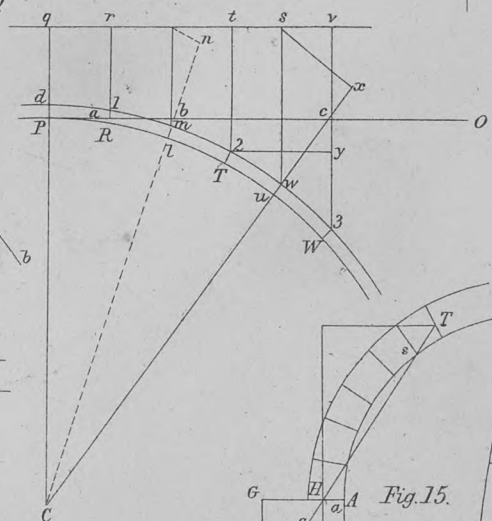


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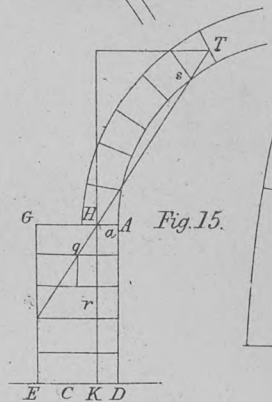


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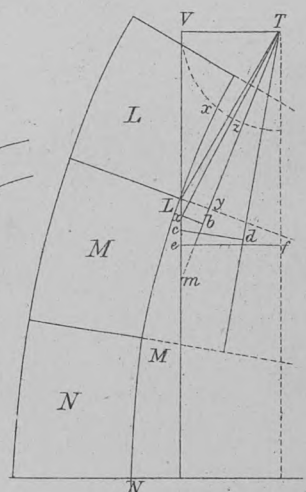


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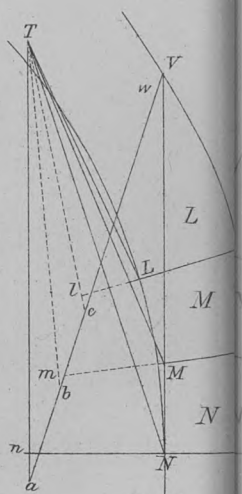


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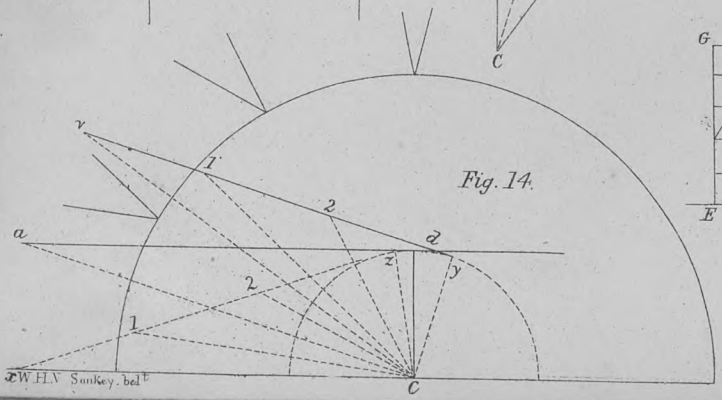


Fig. 14.

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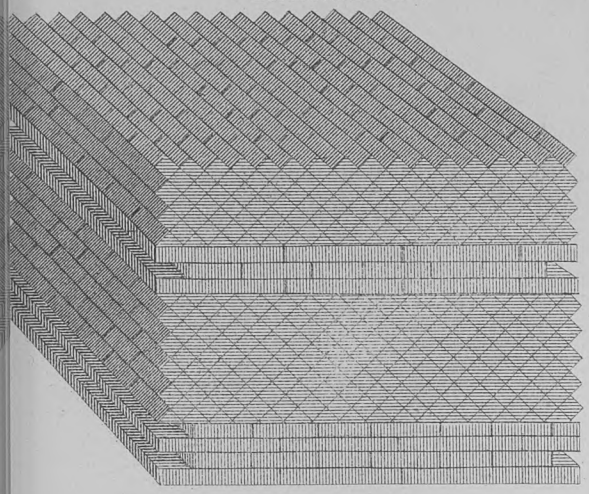


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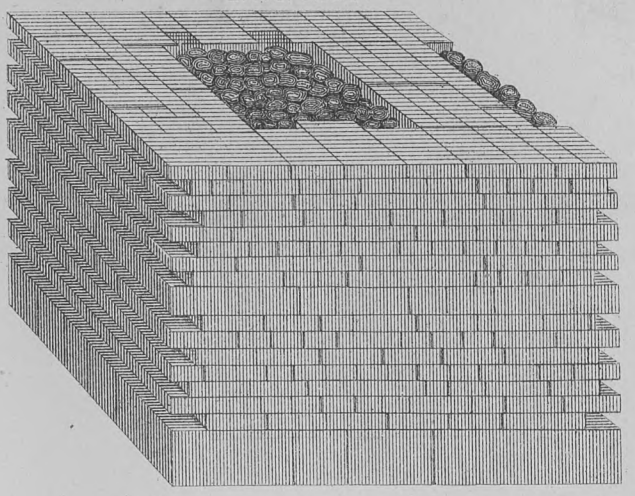


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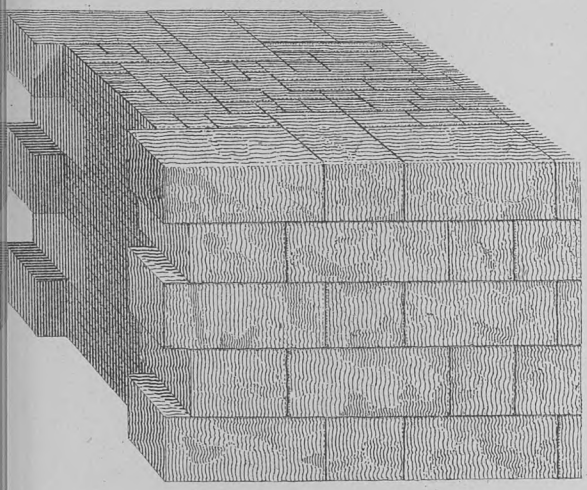


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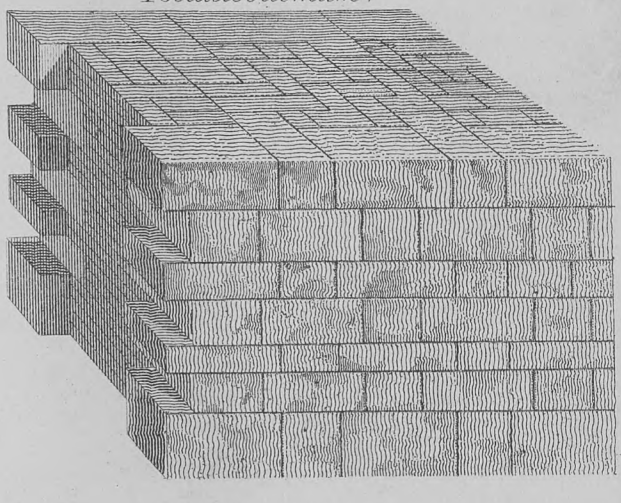


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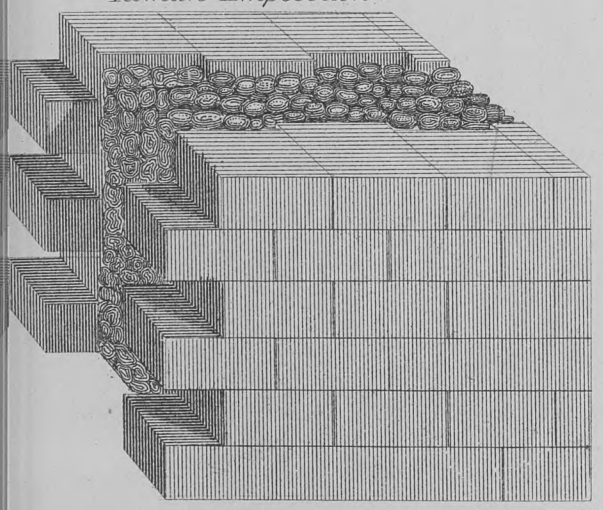
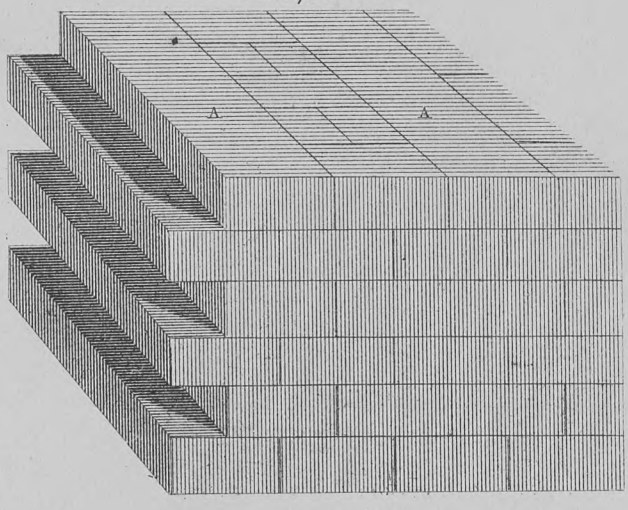


Fig. 6.
Greek Emplection.



by M.A. Nicholson.

Engraved by J.C. Buttre.

STRENGTH OF TIMBER.

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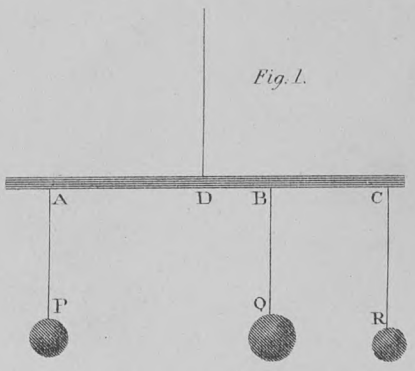


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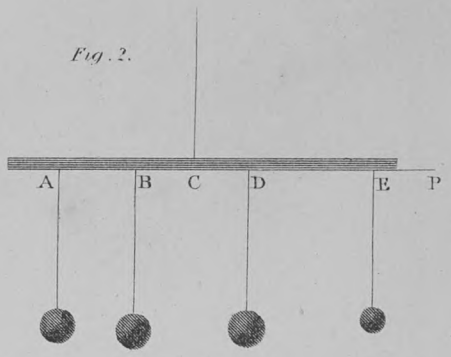


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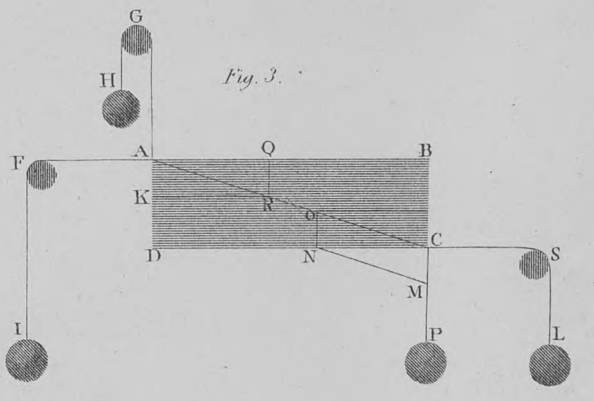


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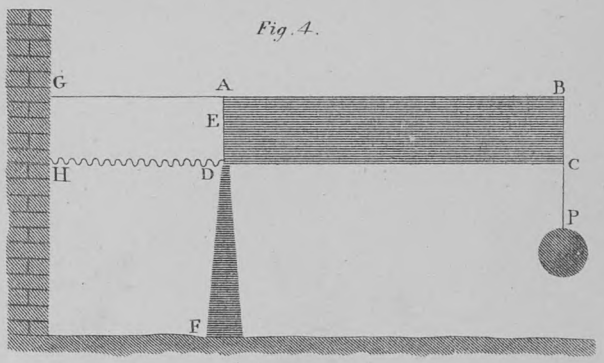


Fig. 5.

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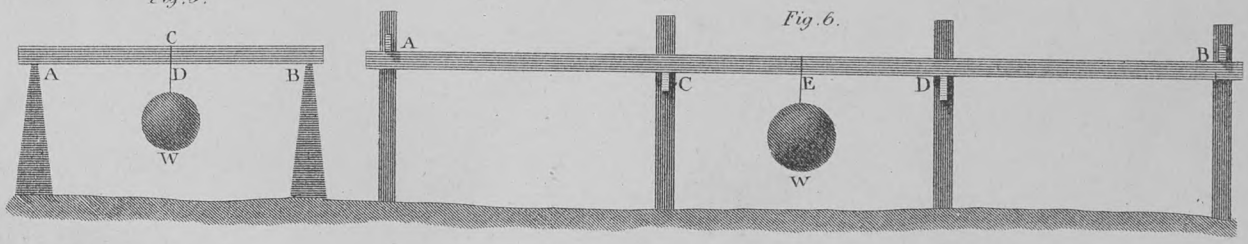


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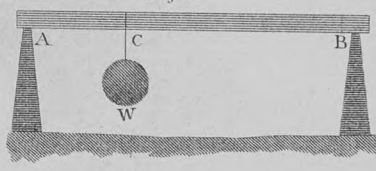


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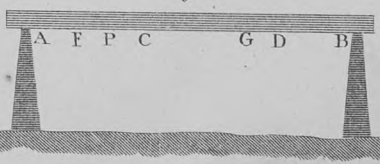


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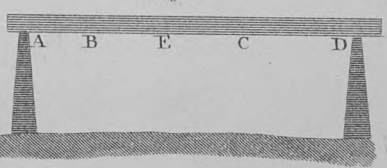


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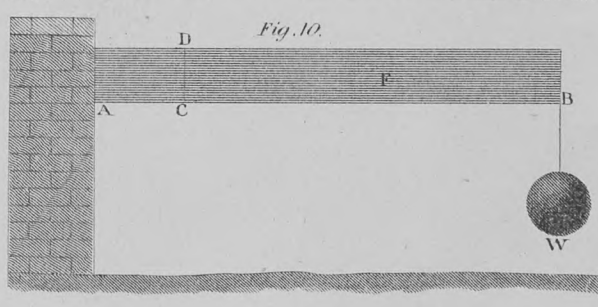
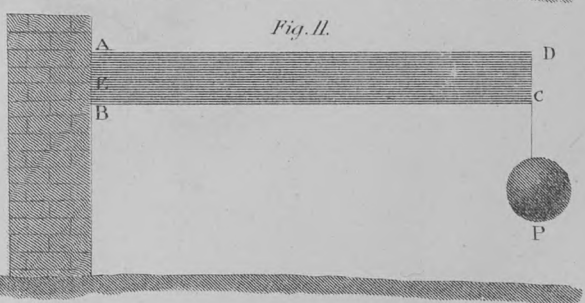


Fig. 11.



Drawn by P. Nicholson.

Engraved by J.

TOOLS.

BRICKLAYERS TOOLS.

Fig 5

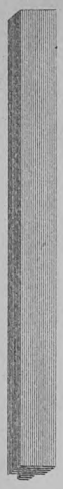


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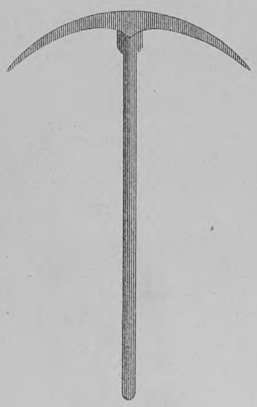


Fig. 2.



Fig. 1.



Fig. 10.

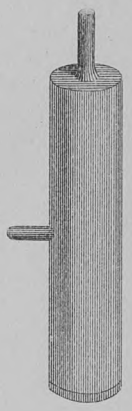


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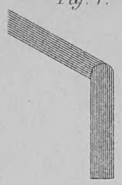


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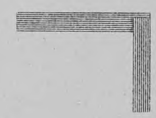


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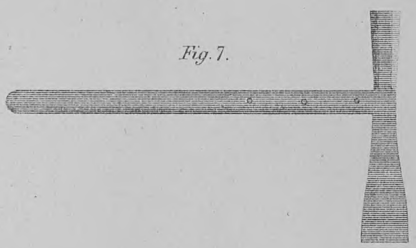


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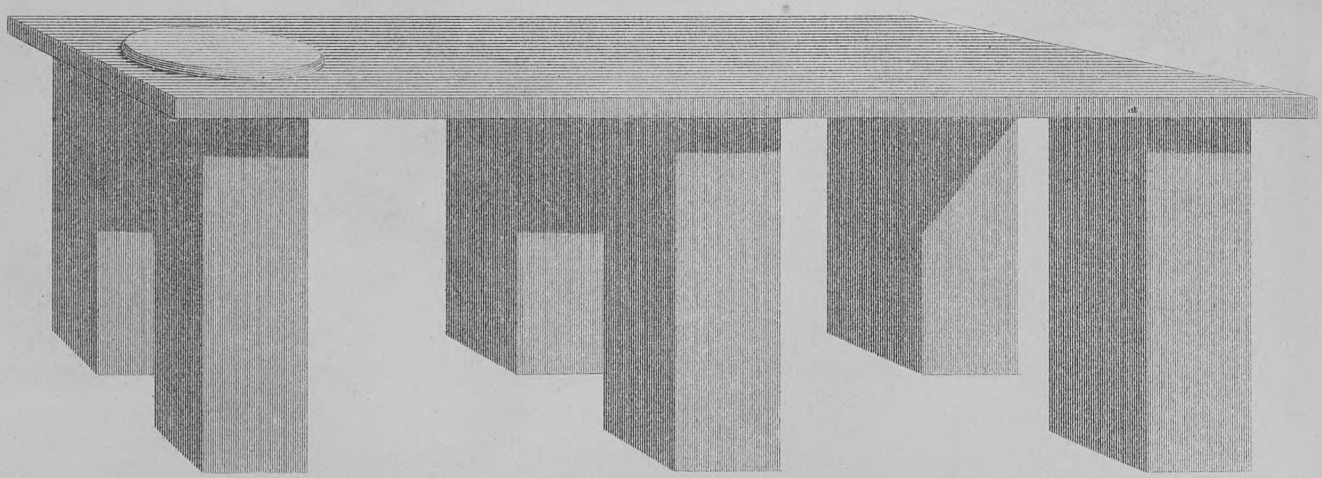
Fig. 6.



Fig. 12.



Fig. 13.



MANicholson delin.

Engd by H Thew

TOOLS.

CARPENTER'S TOOLS.

Fig. 1.

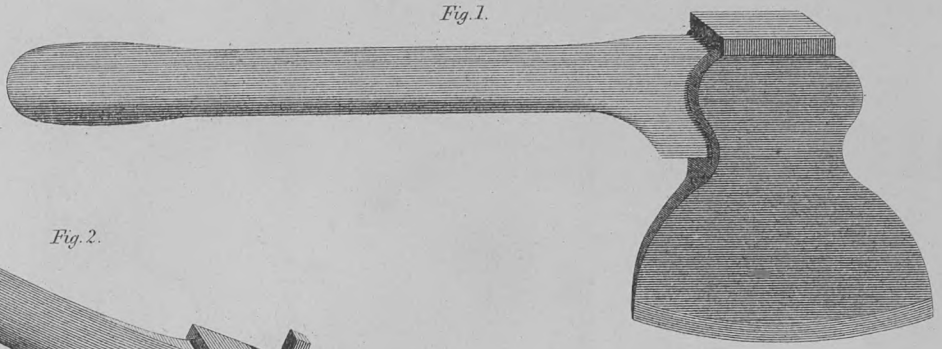


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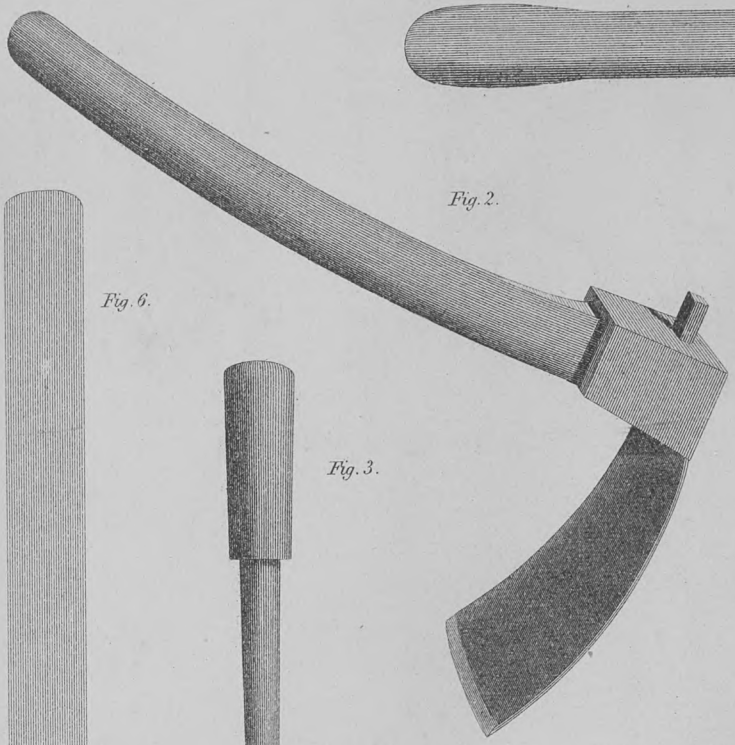


Fig. 6.



Fig. 3.



Fig. 4.

Fig. 5.

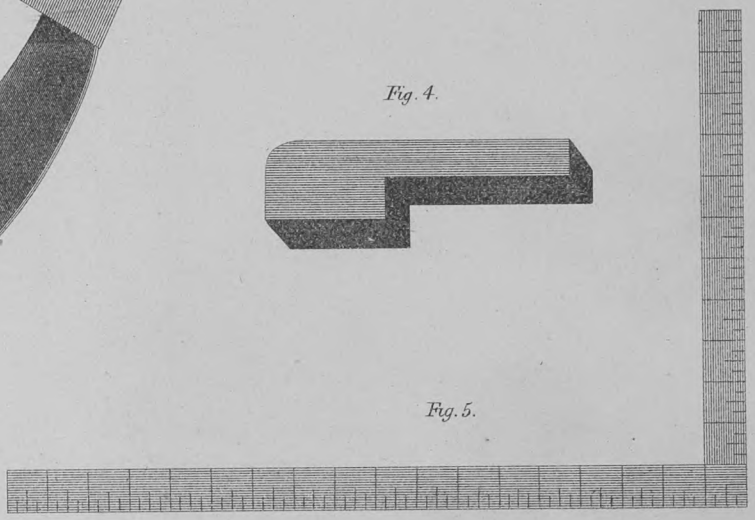


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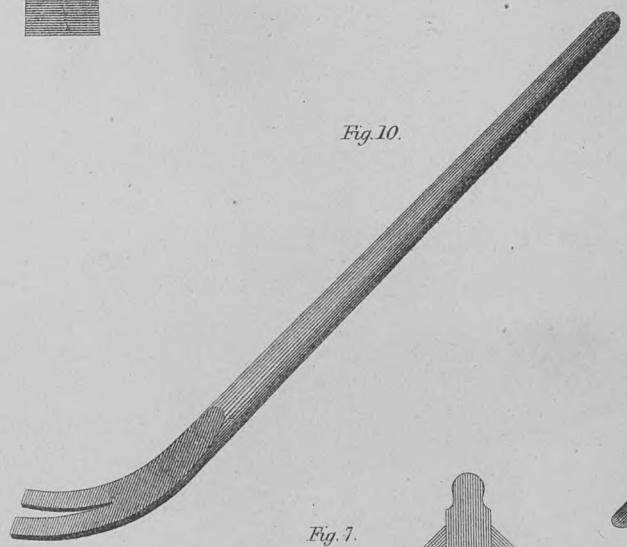


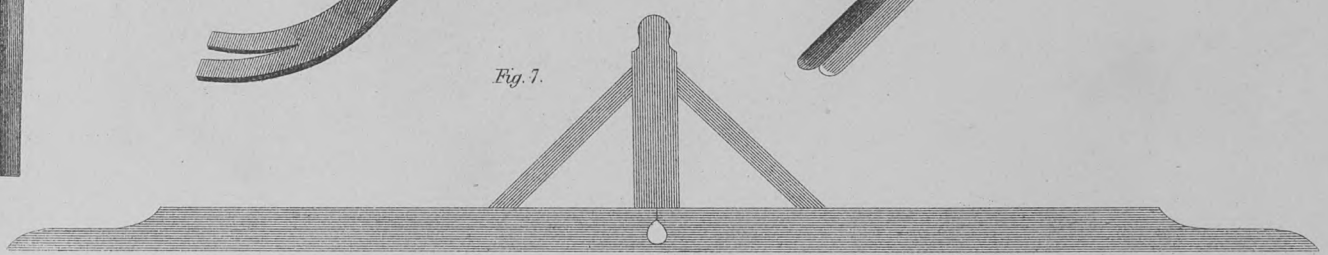
Fig. 8.



Fig. 9.



Fig. 7.



Drawn by M A. Nicholson.

Engraved by R.The

TOOLS.

BELONGING TO JOINERS.

PLATE. I.

Fig. 1.

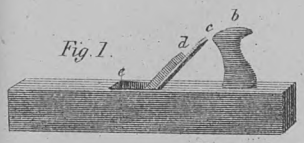


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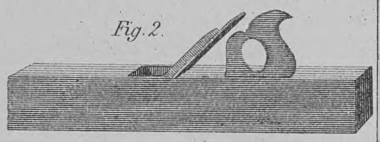


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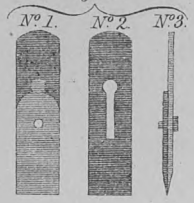


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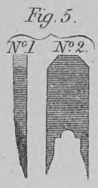


Fig. 3.



Fig. 6.

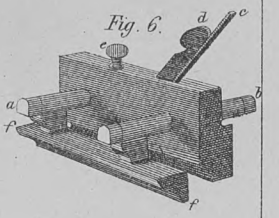


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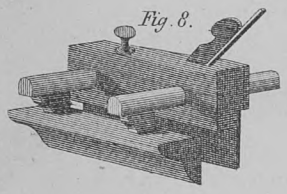


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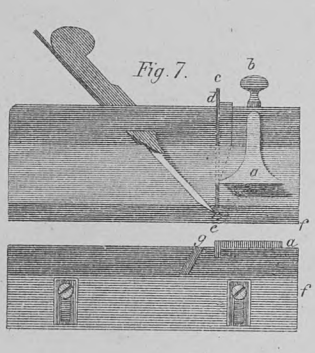


Fig. 11.



Fig. 9.

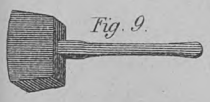


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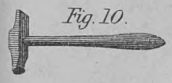


PLATE II.

Fig. 1.



Fig. 2



Fig. 3.



Fig. 4.



Fig. 5.

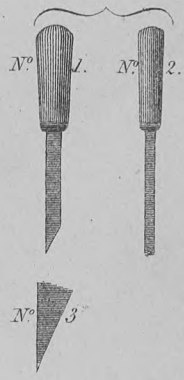


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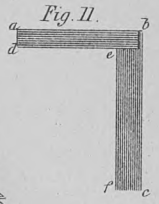


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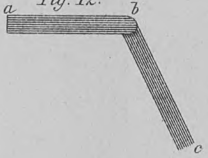


Fig. 13.



Fig. 6



Fig. 7.



Fig. 8.



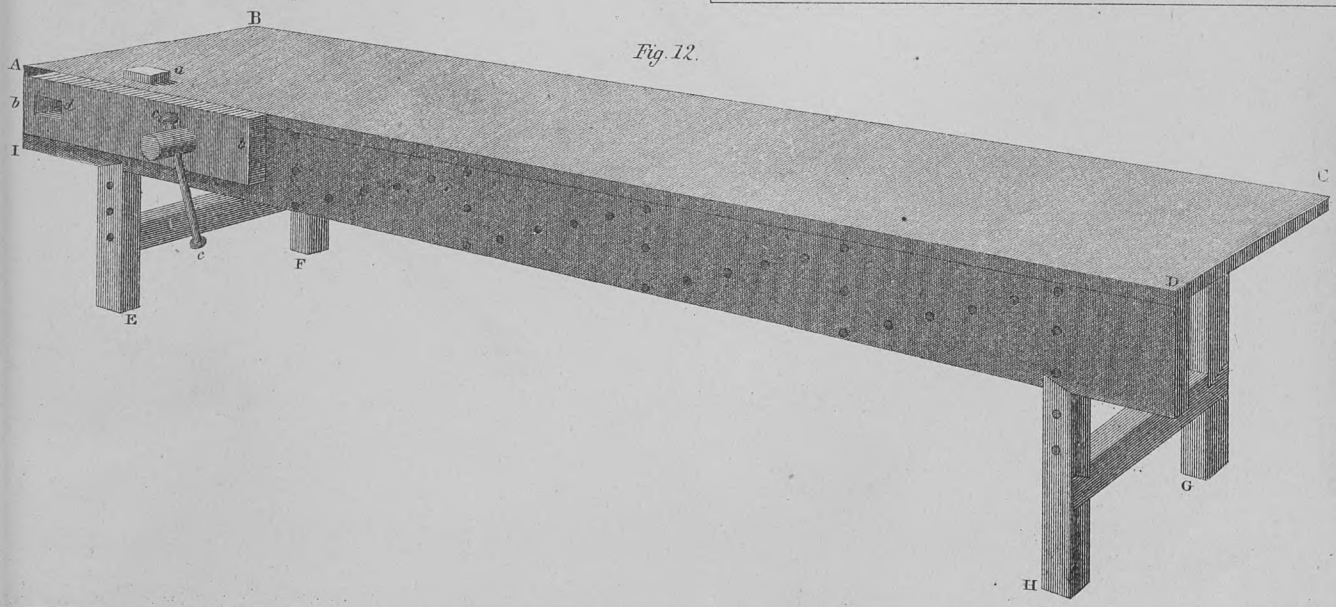
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Fig. 10.

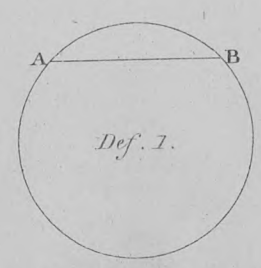


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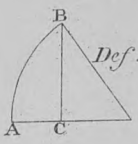


Engᵈ by R. Thew.

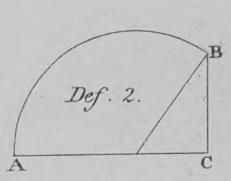
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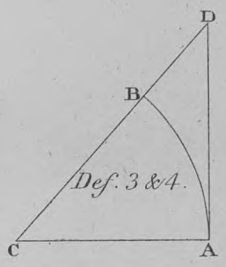
Def. 1.



Def. 2.

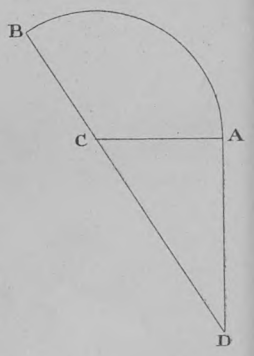


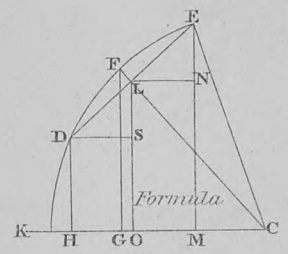
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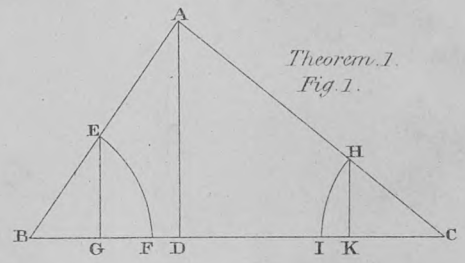
Def. 3 &4.

Def. 3. 4.

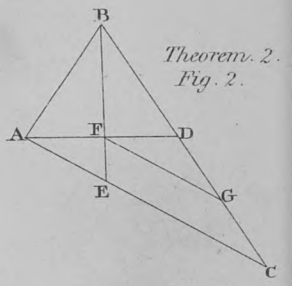




Formula

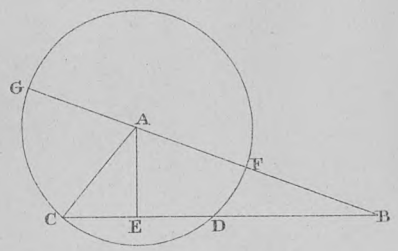


Theorem. 1.
Fig. 1.



Theorem. 2.
Fig. 2.

Theorem. Fig. 3.



Obtuse angled triangle
Cases 1 2 3. 4.

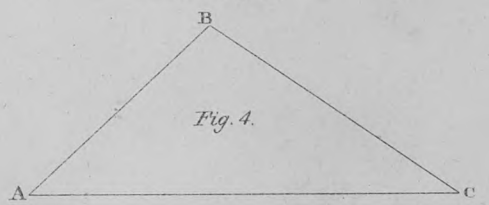


Fig. 4.

Right angled triangle.

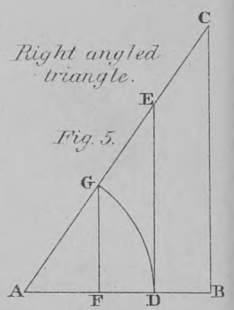
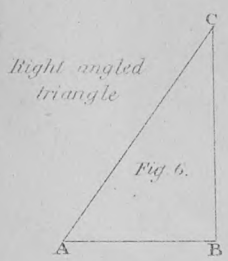
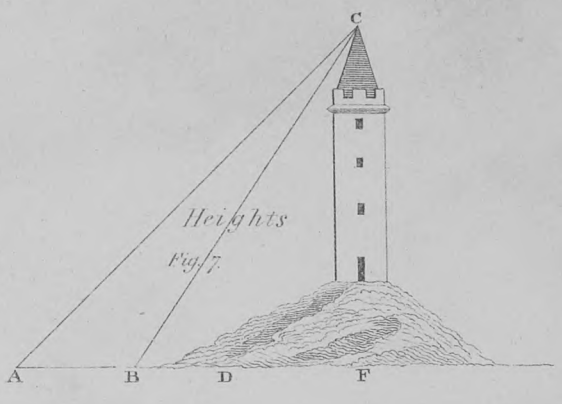


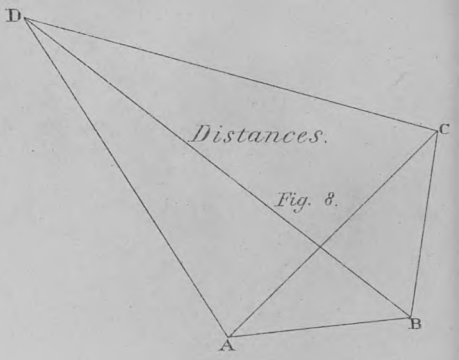
Fig. 5.



Right angled triangle
Fig. 6.



Heights
Fig. 7.



Distances.
Fig. 8.

Drawn by P. Nicholson.

Engraved by B. T.

TRUSS.

PLATE. 1.

Fig. 1. N°1.

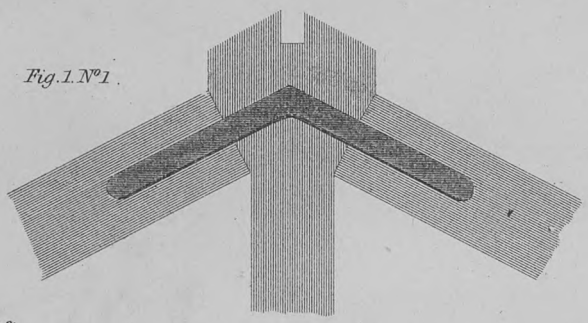
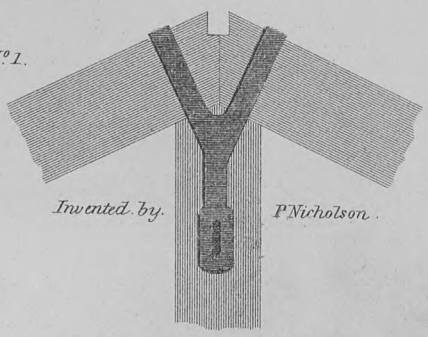


Fig. 2. N°1.



Invented by P. Nicholson.

Fig 1 N° 3.

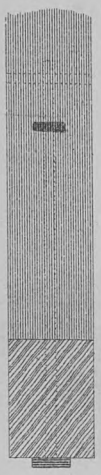


Fig. 1. N° 2

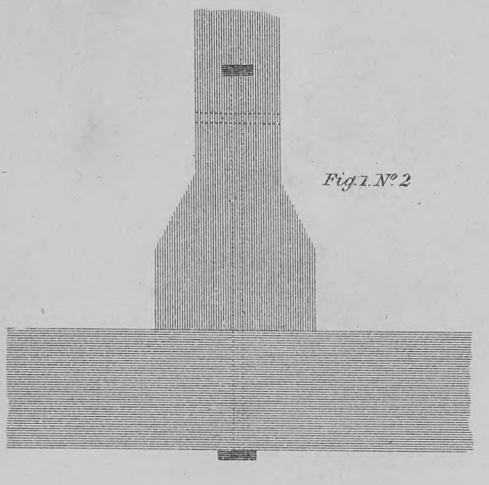


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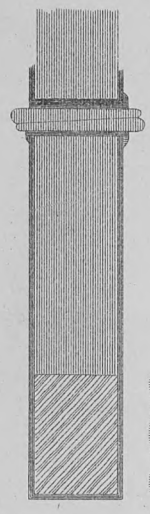


Fig 2 N° 2.

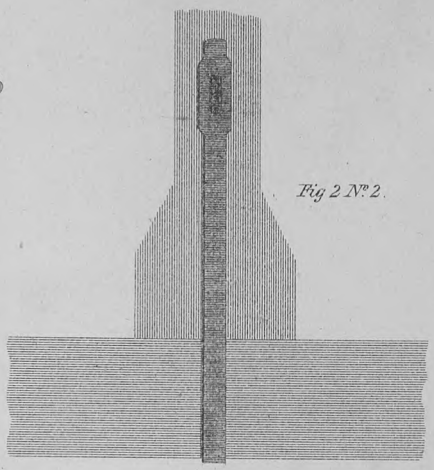
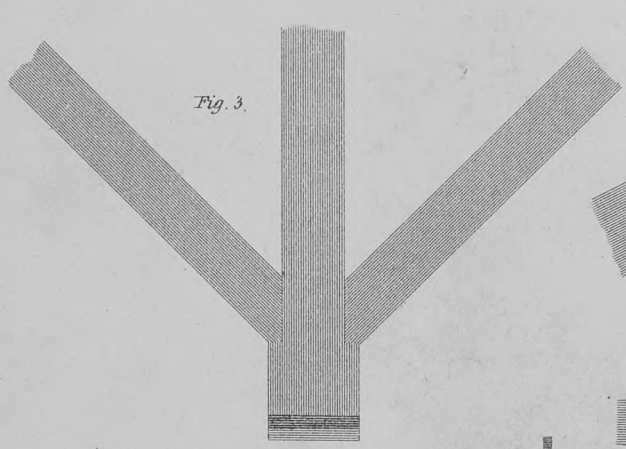


Fig. 3.



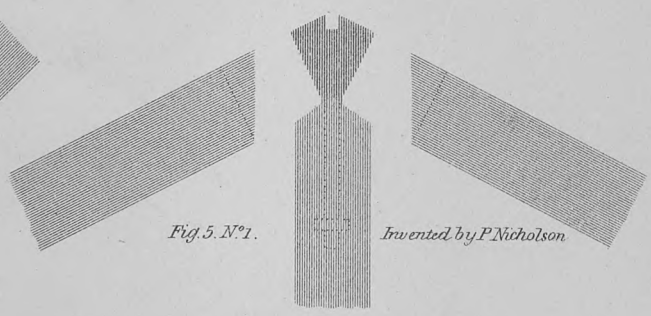


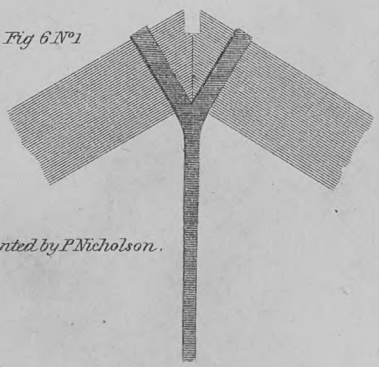
Fig. 5. N°1.

Invented by P. Nicholson

Fig. 5 N° 2.

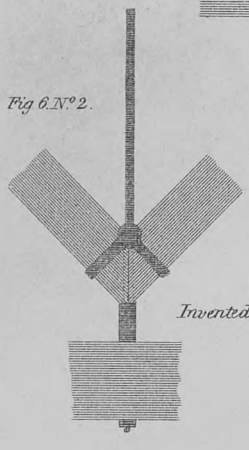


Fig 6. N°1



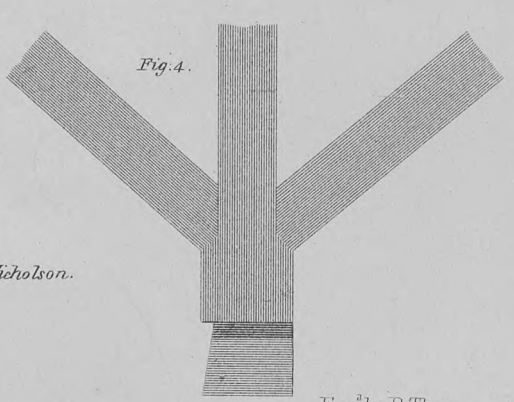
Invented by P. Nicholson.

Fig 6. N°2.



Invented by P. Nicholson.

Fig. 4.

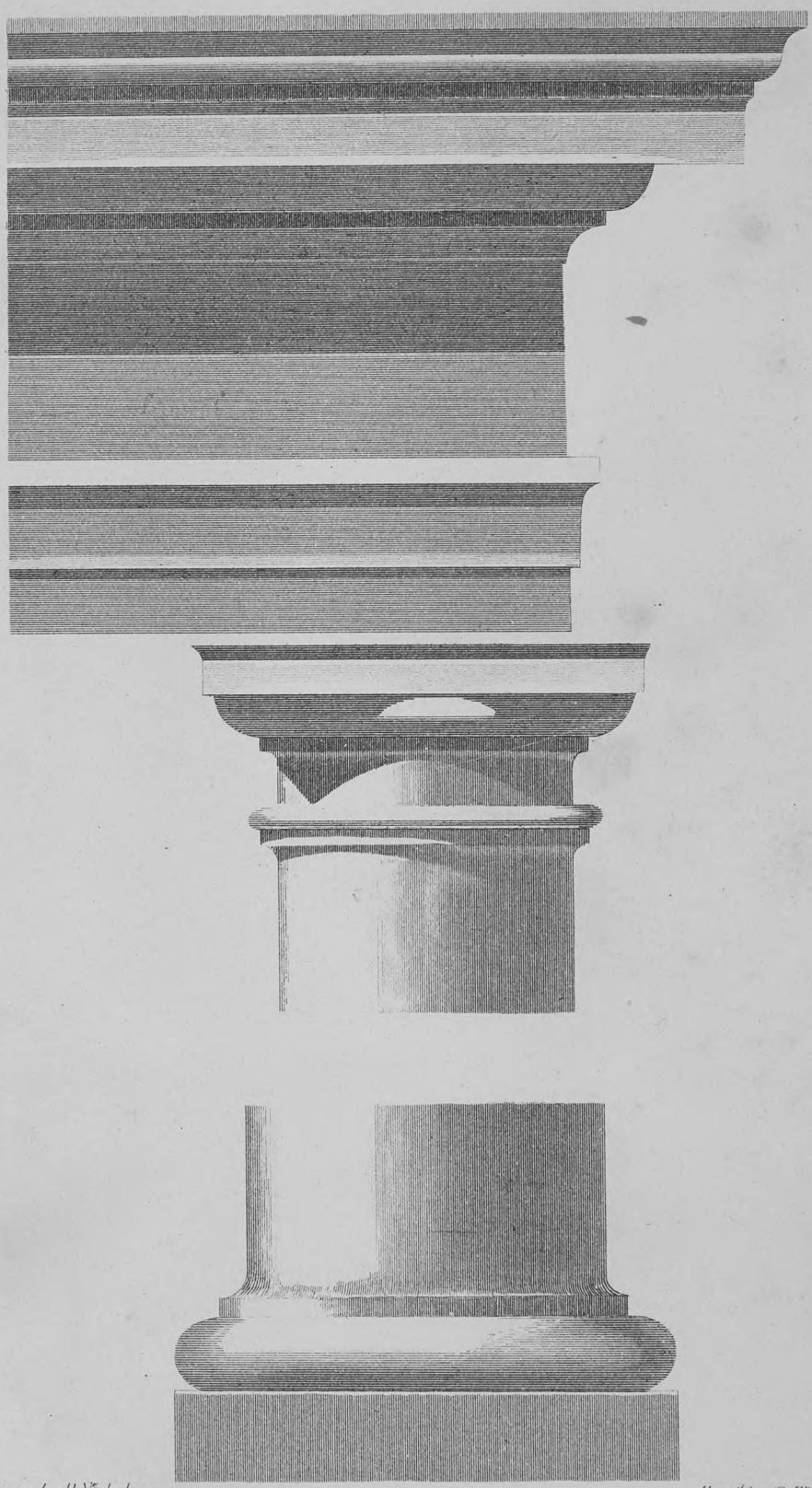


Drawn by. P. Nicholson.

Engd by R. Thew.

TUSCAN ORDER.

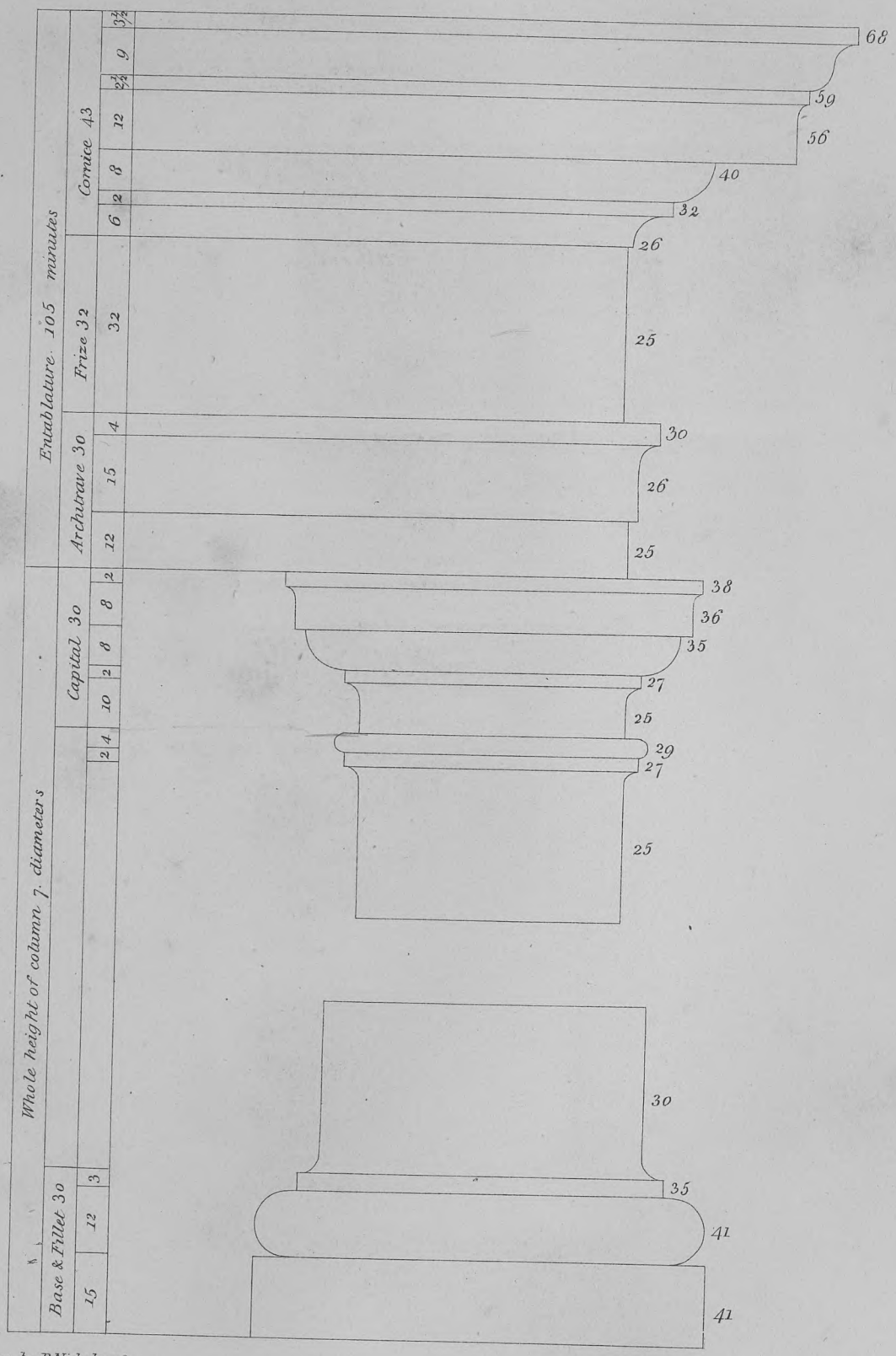
PLATE I.



Drawn by P. Nicholson. *Engd by R. Thew.*

TUSCAN ORDER.

PLATE. 2.

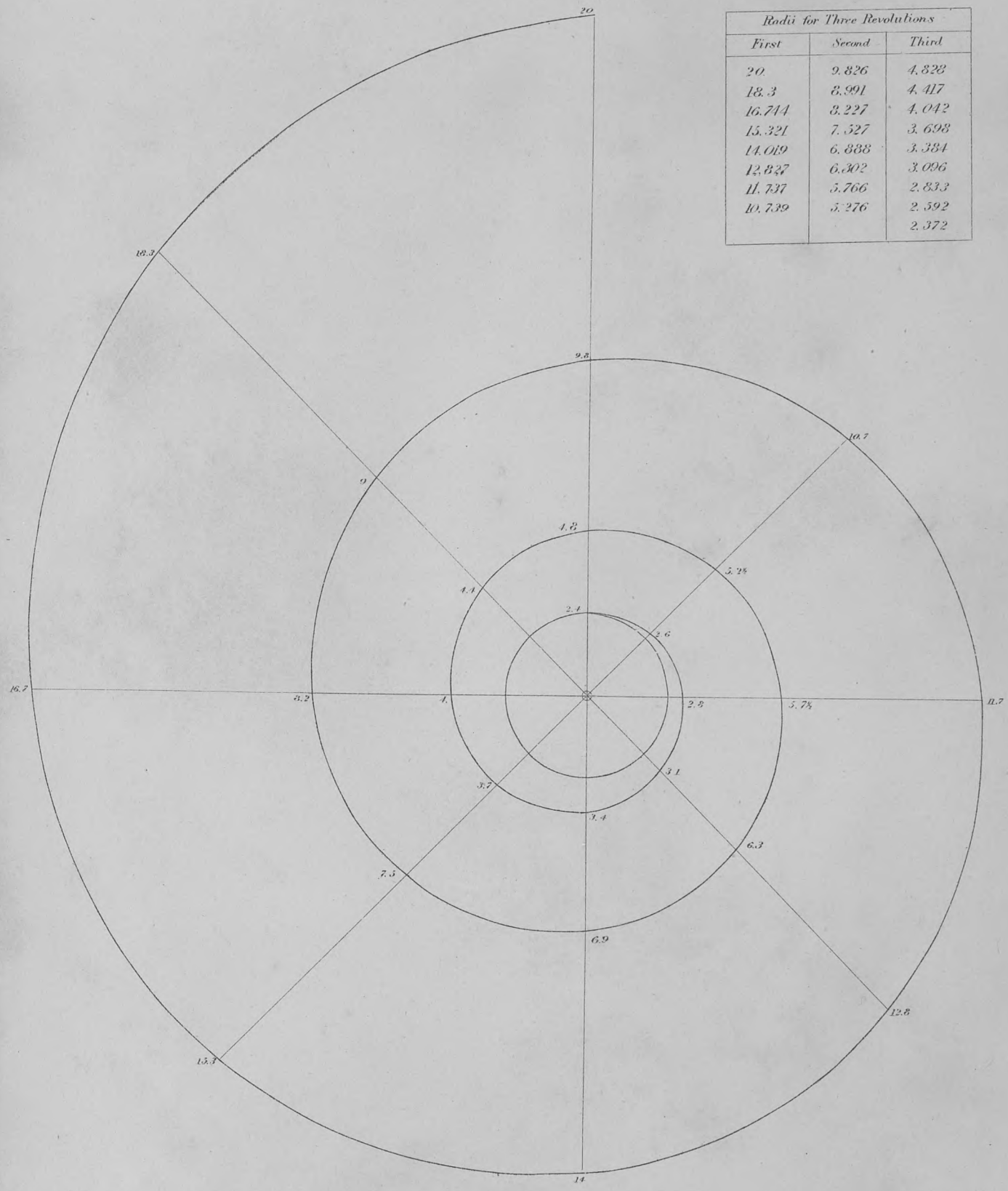


Drawn by P Nicholson.

Eng.d by R. Thew.

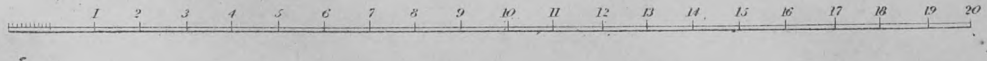
VOLUTE.

Radii for Three Revolutions		
First	Second	Third
20.	9.826	4.828
18.3	8.991	4.417
16.714	8.227	4.042
15.321	7.527	3.698
14.019	6.888	3.384
12.827	6.302	3.096
11.737	5.766	2.833
10.739	5.276	2.592
		2.372

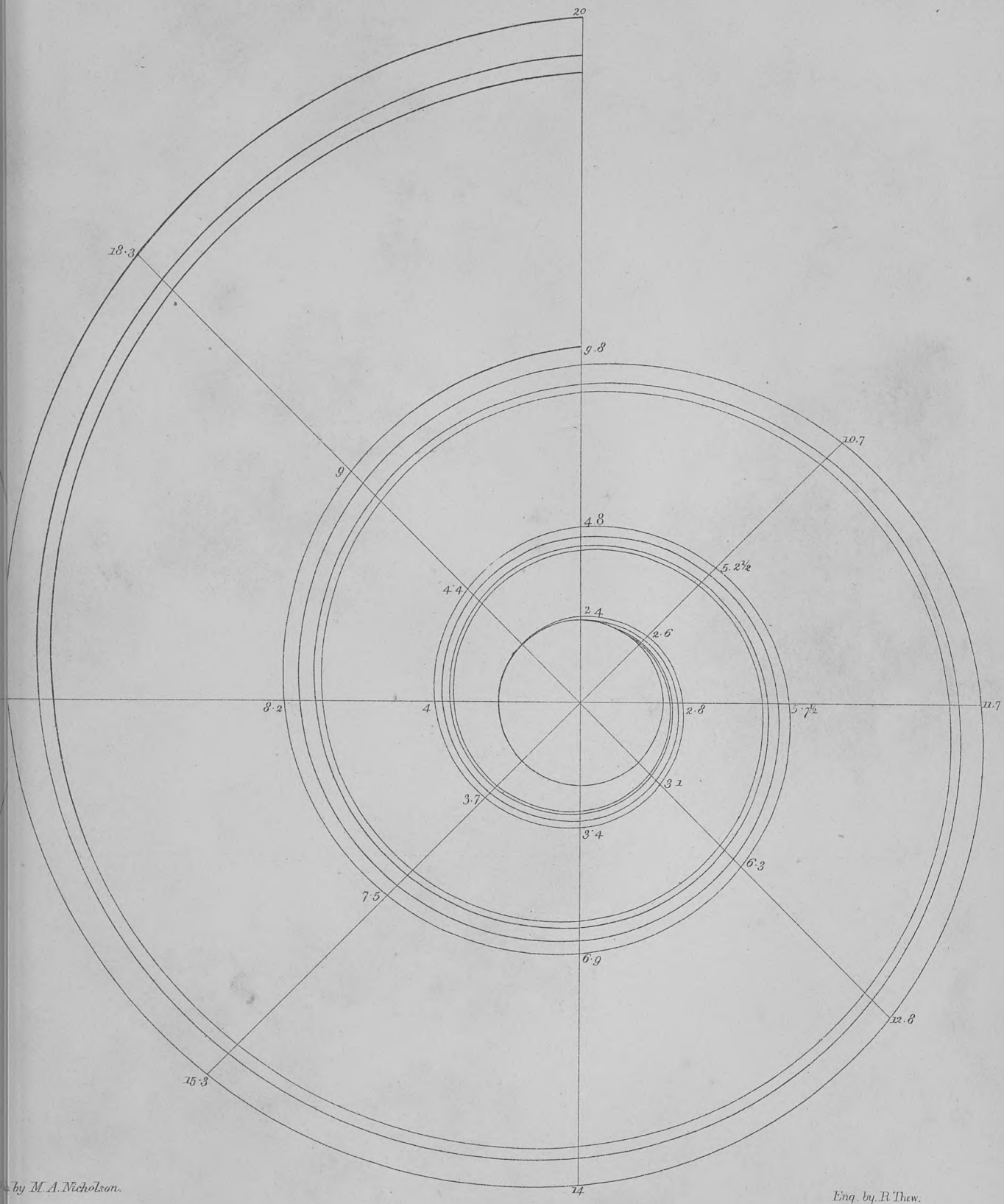


Drawn by M.A. Nicholson

Engraved by J.C. Buttre



VOLUTE.



Eng. by M.A. Nicholson.

Eng. by R. Thew.

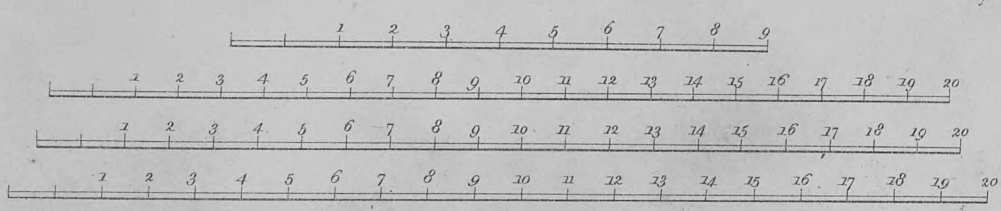


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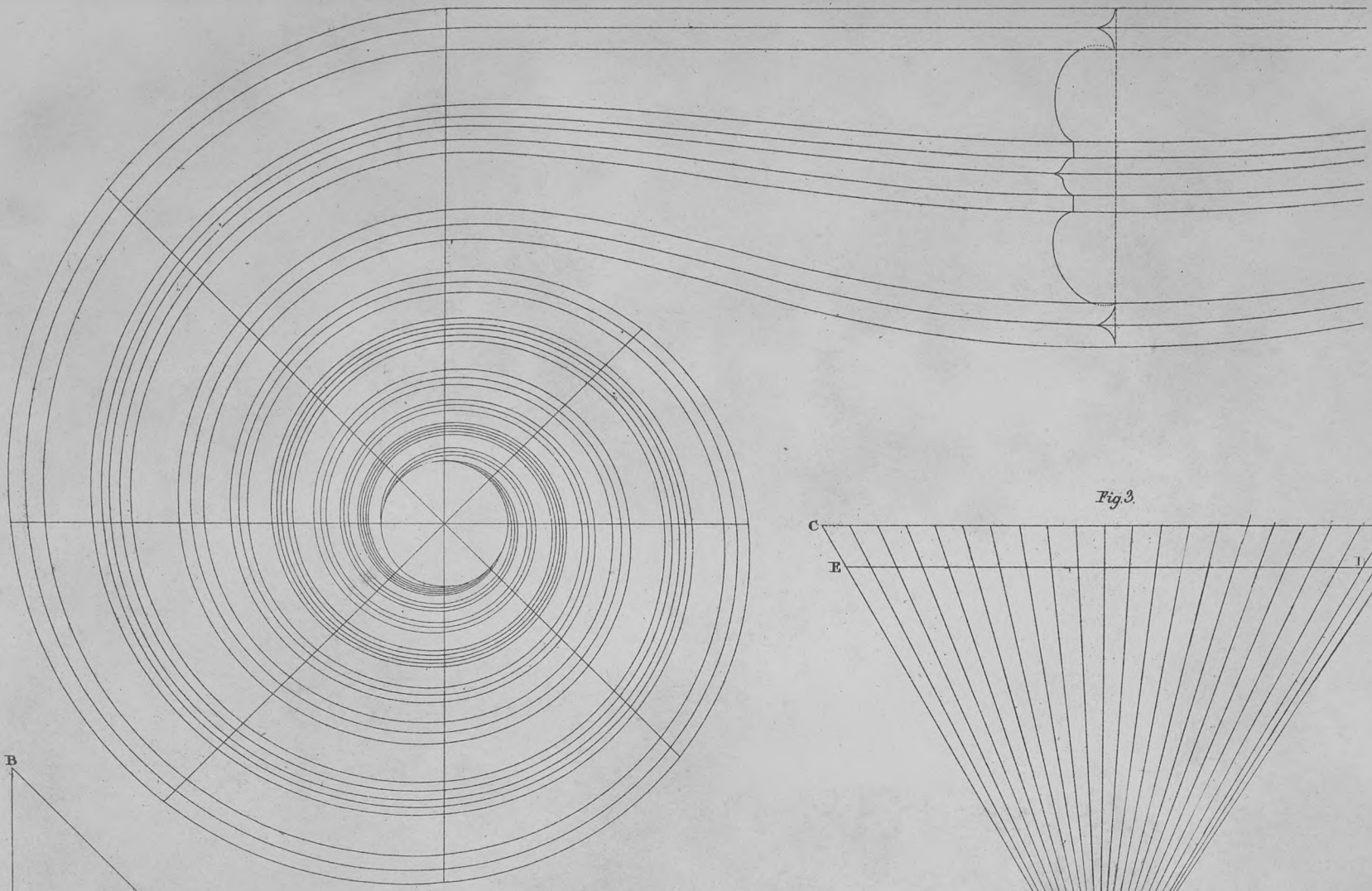
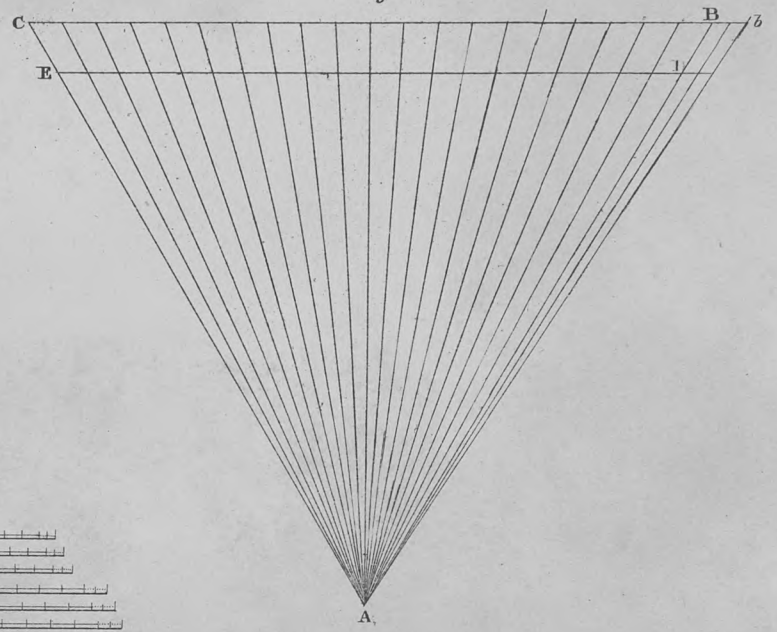


Fig. 3.



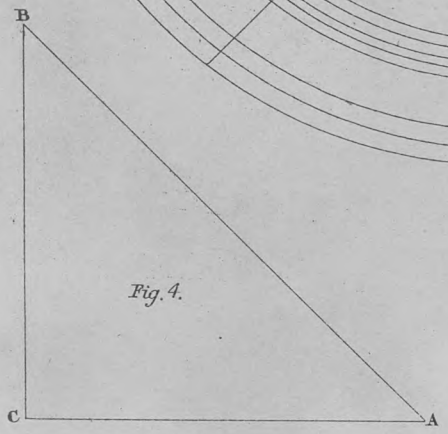
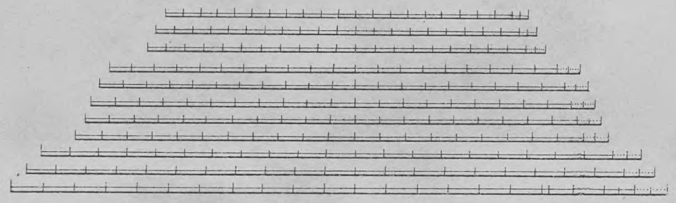


Fig. 4.

Fig. 2.



Invented & Drawn by P. Nicholson.

Engd by R. Thew.

VOLUTE.

Fig. 4.

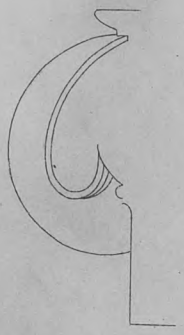


Fig. 1.

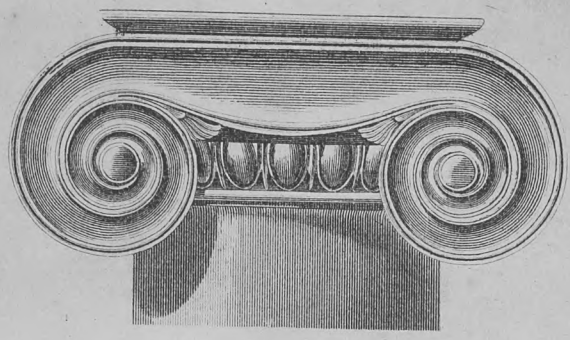


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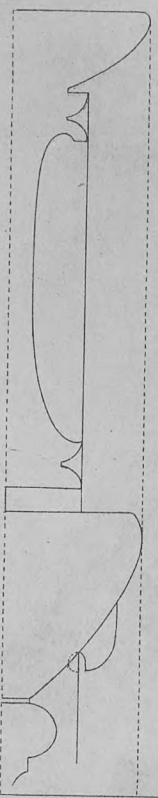
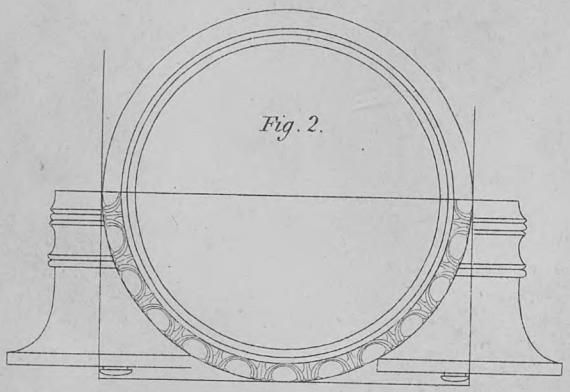


Fig. 3.



Fig. 2.



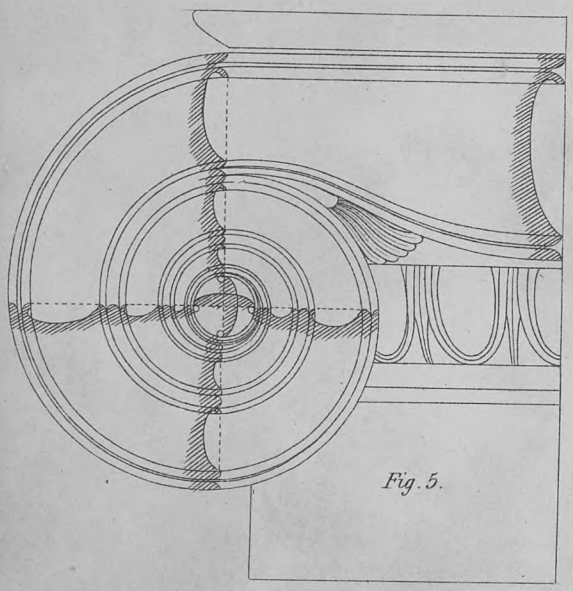


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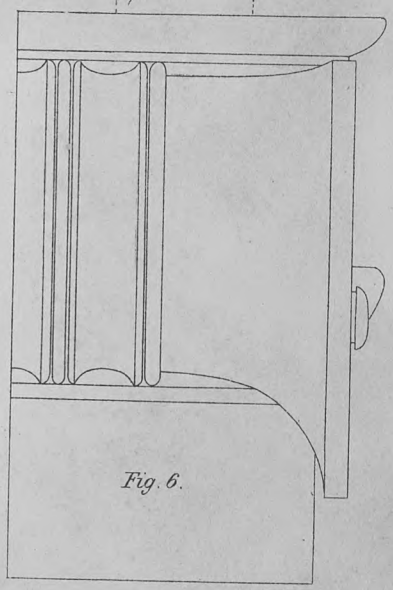
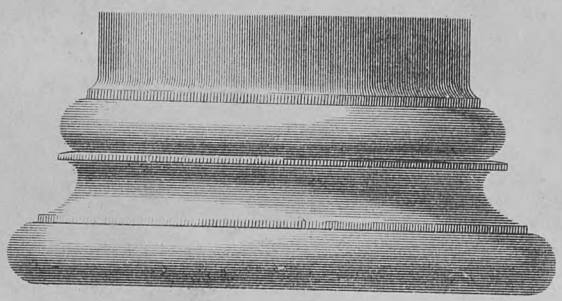


Fig. 6.

Fig. 8.



WINDOWS.

Fig 1 N° 1

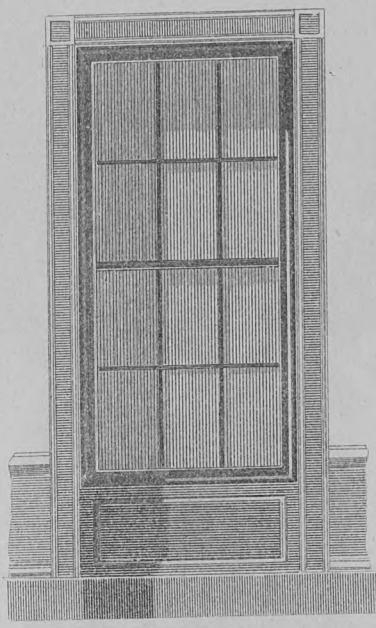


Fig 1 N° 2

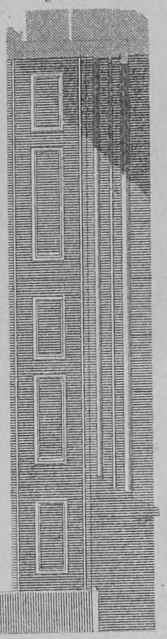


Fig 2

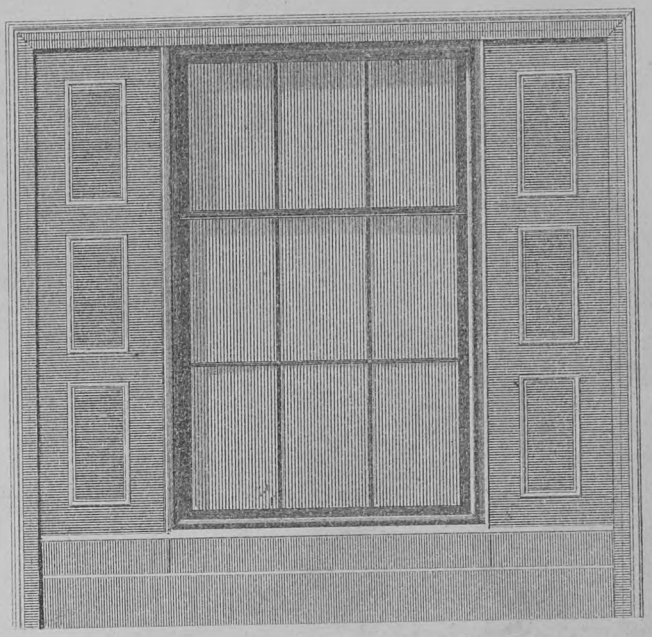


Fig. 3.

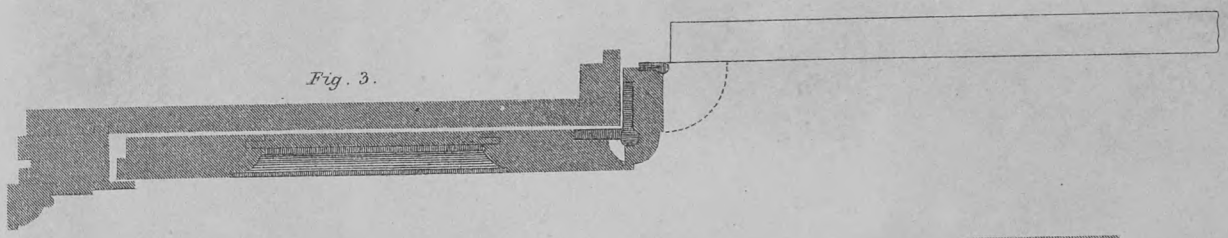


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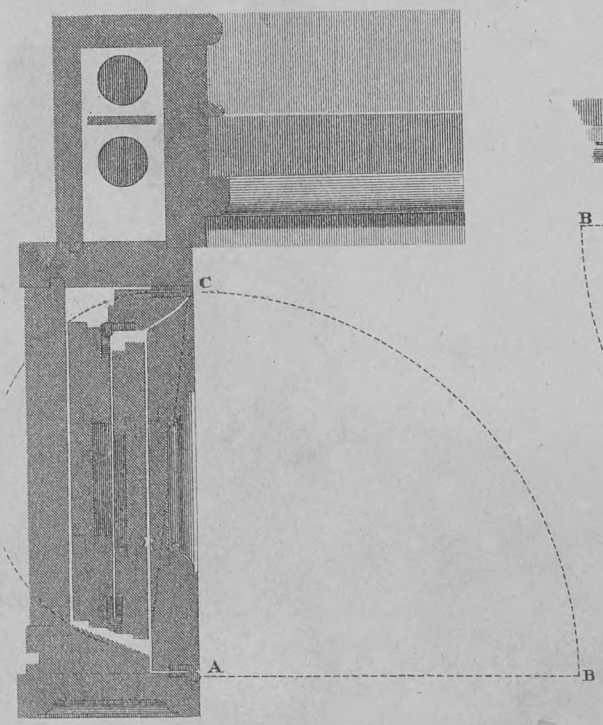
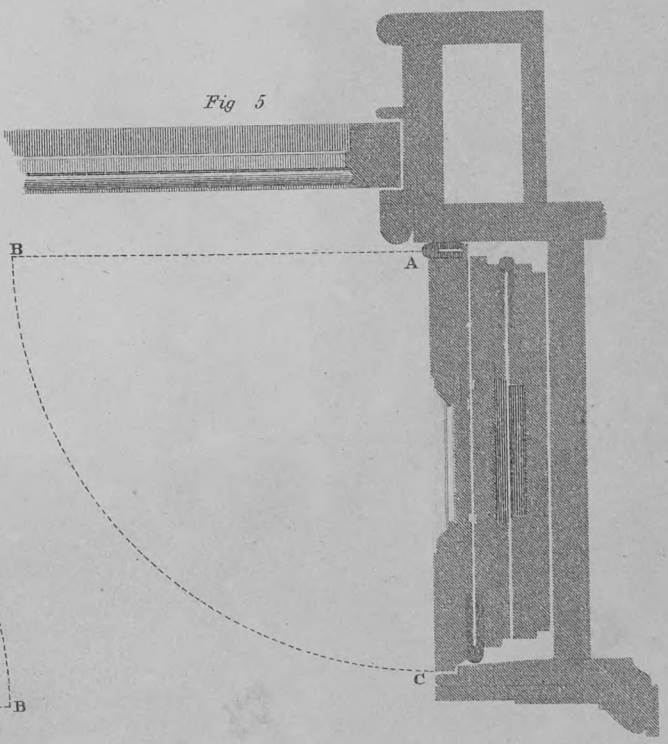


Fig 5



Drawn by J. P. Nicholson.

Engd. by R. Thew.

DO NOT CIRCULATE